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GROUND WATER

IN

NORTHWESTERN PENNSYLVANIA

R. M. LEGGETTE

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BULLETIN W 3

GROUND WATER
IN
NORTHWESTERN PENNSYLVANIA

By

R. M. LEGGETTE

of the U. S. Geological Survey

With Analyses by Margaret D. Foster, W. L. Lamar, and S. K. Love

(Prepared in cooperation between the United States Geological Survey and the Pennsylvania Topographic and Geologic Survey)

Department of Internal Affairs
THOMAS A. LOGUE, *Secretary*
Topographic and Geologic Survey
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Harrisburg, Pa.
1936

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Ground Water in
Northwestern Pennsylvania

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CONTENTS

	Page
Abstract	1
Introduction	1
Purpose of the investigation	2
Location of the area	2
Population	3
Earlier studies	3
Bibliography	5
Climate	6
Precipitation	6
Temperature	9
Frost	9
Geomorphology	12
Major features	12
Pre-Wisconsin drainage	15
Geology	26
Surface deposits	26
Recent alluvium	26
Pleistocene	27
Glacial drift	27
General features	27
Till	28
Outwash	28
Carmichaels formation	29
Rock formations	31
Carboniferous system	31
Pennsylvania series	31
General features	31
Monongahela formation	31
Conemaugh formation	32
Allegheny formation	32
Pottsville formation	33
Unconformity between the Mississippian and Pennsylvanian series	36
Mississippian series	37
Mauch Chunk formation	37
Loyalhanna limestone	38
Pocono group	38
Upper Devonian or Mississippian rocks	39
Devonian system	39
Upper Devonian series	39
Structure	39
Ground water	40
Source	40
Occurrence	42
Glacial drift	45
Sandstone	45
Shale	46
Coal	46
Recovery	46
Quality of water	49
Analyses of waters	54
Description by counties	64
Explanation of data	64
Armstrong County	65
Beaver County	76
Clarion County	95
Crawford County	109
Erie County	128
Forest County	141
Indiana County	145
Jefferson County	157
Lawrence County	166
Mercer County	178
Venango County	192
Warren County	200
Index	212

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ILLUSTRATIONS

		Page
Plate 1.	Map of northwestern Pennsylvania and adjoining area showing present drainage pattern	In pocket
2.	Map of northwestern Pennsylvania and adjoining area showing buried valley pattern	In pocket
3.	A. Glacial striae on surface of Sharon sandstone at Quarry Hill, about 2 miles southeast of Greenville, Mercer County; B. Fore-set beds of Wisconsin glacial outwash in gravel pit 1 mile southwest of Wesley, Venango County	19
4.	Map of northwestern Pennsylvania showing glacial outwash and location of wells	In pocket
5.	Geologic map of northwestern Pennsylvania	In pocket
6.	Graphs showing fluctuations of water level in seven shallow wells in northwestern Pennsylvania	42
7.	A. An open joint in a sandstone of the Conewango (?) formation near West Hickory, Forest County	44
	B. Thin-bedded sandstone exposed in south bank of Allegheny River, about 1 mile upstream from Oil City, Venango County	47
8.	A. Pockets of gravel incorporated in laminated silt 1 mile north of Pulaski, Lawrence County	166
	B. Exposure of glacial silt 1 mile north of Pulaski, Lawrence County	167
9.	A. Exposure of terrace along Little Brokenstraw Creek about 2½ miles south of Wrightsville, Warren County; B. Pikes Rocks, 2 miles northeast of Wrightsville, Warren County	203

Fig. 1.	Index map of Pennsylvania showing areas covered by groundwater reports	2
2.	Map of western Pennsylvania showing climatologic stations and lines of average annual precipitation in inches	7
3.	Annual precipitation at four stations in northwestern Pennsylvania	9
4.	Monthly precipitation for three years at three stations in northwestern Pennsylvania	10
5.	Physiographic divisions of Pennsylvania and the surrounding area (after Fenneman)	12
6.	Profiles of Lake Erie escarpment in northwestern Pennsylvania	13
7.	Map showing restoration of uplifted Harrisburg (Allegheny) peneplain	15
8.	Ideal section from Scandia to Tiona showing conditions at the close of Connoquenessing sedimentation	36
9.	Hydrograph of dug well in Sligo, Clarion County and precipitation at Parkers Landing	41
10.	Map of Monaca and vicinity showing location of infiltration crib in Ohio River and near-by wells	86
11.	Graphic representation of analyses of water from Ohio River, Monaca crib, and wells at Beaver borough	87
12.	Graphic representation of partial analyses of water from Ohio River, Monaca crib, and three near-by wells, Beaver County	88
13.	Cross section showing buried valley about 4½ miles east of Crossingville	110
14.	Logs of four wells near Meadville, Crawford County	118
15.	Drawdown curve of observation well near Meadville	119

GROUND WATER IN NORTHWESTERN PENNSYLVANIA

By R. M. LEGGETTE

ABSTRACT

The area covered in this report includes Armstrong, Beaver, Clarion, Crawford, Erie, Forest, Indiana, Jefferson, Lawrence, Mercer, Venango, and Warren Counties, in northwestern Pennsylvania. Many previously published geologic reports, particularly those of the Second Pennsylvania Geological Survey, were freely used in the preparation of this report. The hydrologic data were obtained in the field, chiefly by interviewing private, industrial, and municipal well owners and well drillers. About half of the time spent in the field was devoted to the study of the glacial deposits, the most important source of ground water.

The average annual precipitation in the area ranges from about 33 to 46 inches. In general, June and July are the wettest months and February the driest. The average mean annual temperature is about 49°F. The average length of the growing season ranges from 193 days along the shore of Lake Erie to about 113 days in other parts of the area.

The area all lies within the Appalachian Plateau province. The northwestern part of the area was covered by at least two ice sheets in the Pleistocene epoch. Most of the area is drained by the Ohio River and its tributaries. At least two peneplains have been recognized in the area, the Harrisburg and the Worthington. Many drainage changes have taken place since preglacial time, and this has resulted in a large number of buried valleys, which because of their importance as sources of ground water were studied in considerable detail. It is believed that most of these buried valleys originated during glacial time and not in preglacial time, as was supposed by earlier workers. In the present state of knowledge many preglacial drainage patterns, postulated by other workers, do not seem well substantiated.

In the glaciated parts of the area the surface deposits are chiefly glacial till. The sand and gravel deposits in the buried valleys are by far the most productive source of large quantities of ground water in the area. The bedrock exposed in the area extends from the Monongahela formation, of the Pennsylvanian series, down to the rocks forming a part of the upper Devonian series. In general, the sandstone members of all the bedrock formations yield potable water in parts of the area. However, most of the sandstones are irregular, and where they become shaly they are poor sources of water. In most of the area the rocks dip so slightly that they appear to be essentially horizontal. However, in the southeastern part, along the Allegheny Front, the dip is as much as 1,000 feet to the mile.

The source and occurrence of ground water are described, together with the water-bearing properties of the various types of rock. The principles governing the recovery of ground water by means of wells are described, particularly with reference to the use of screens in wells ending in deposits of sand and gravel.

The analyses of 171 samples of water are given in tabular form, together with brief statements of the significance of the various dissolved constituents commonly found in natural waters. A summary table is given showing the maximum, average, and minimum amount of dissolved mineral matter in waters from glacial drift, sandstone, and shale. A brief description of the treatment of water for removal of iron is given.

The geology and ground-water conditions are described in separate sections for each county. A table of well data for each county is given.

INTRODUCTION

PURPOSE OF THE INVESTIGATION

This investigation is a part of a larger program undertaken by the Pennsylvania Topographic and Geologic Survey in cooperation with the United States Geological Survey to determine the ground-water conditions in the entire State. Although a considerable part of the area covered by this report is not highly industrialized, a great number of the smaller towns have industries, many of which require considerable quantities of water and some of which require water of certain quality. Municipal as well as domestic water supplies are to a great extent derived from water stored in the ground. Many of the present users of ground water are confronted with the problem of obtaining larger quantities of water or water of more desirable quality. It is with the hope of helping solve these present-day problems, as well as problems that will arise in the future with the further development of the area, that this investigation was made.

LOCATION OF THE AREA

The area described in this report covers 8,044 square miles in the northwestern part of Pennsylvania and includes Armstrong, Beaver, Clarion, Crawford, Erie, Forest, Indiana, Jefferson, Lawrence, Mercer, Venango, and Warren Counties. (See fig. 1.) Its longest dimension from north to south is about 125 miles and from east to west about 95 miles.

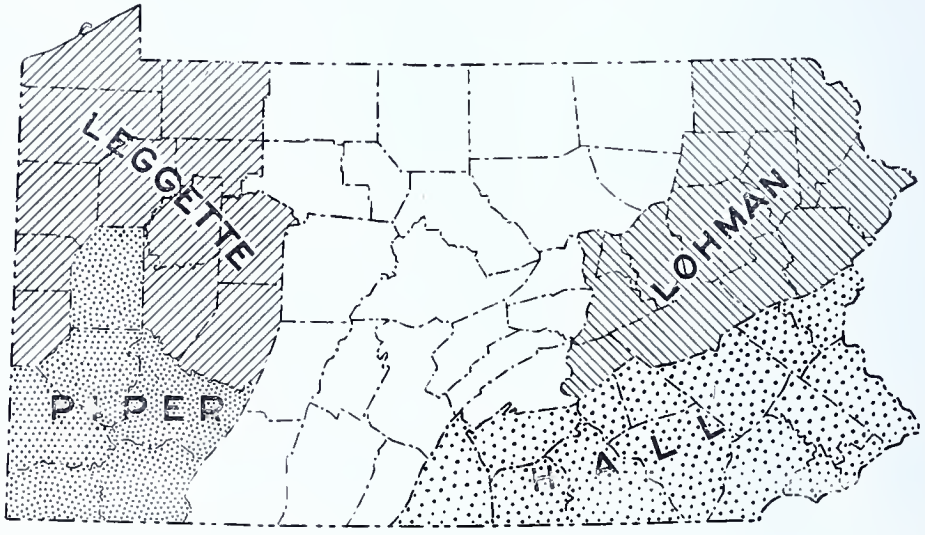


Figure 1.—Index map of Pennsylvania showing areas covered by Ground Water reports

The district is bordered on the west by the States of Ohio and West Virginia, on the north by Lake Erie and New York State, and on the south and east by the adjoining counties of Pennsylvania. Most of the area lies between meridians 79° and 80° 30′ and parallels 40° and 42°.

POPULATION

According to the Federal Bureau of the Census, the 12 counties had a combined population of 935,020 in 1930. The 10 largest cities make

up about 35 per cent of the total population, Erie ranking first with 115,967 and Farrell ranking tenth with 14,359. Towns of less than 5,000 together with the rural districts comprise 52 per cent of the total population of the area. In 1930 the population per square mile for the 12 counties was 116. Outside of the 26 towns of more than 5,000 population, there are, on the average, about 60 inhabitants to the square mile.

According to the Federal census of agriculture in 1930 there were 33,026 farms averaging about 89 acres to the farm. Of the total land area about 57 per cent was in farms in 1930, as compared with about 68 per cent in 1920.

EARLIER STUDIES

The Pennsylvania Second Geological Survey from 1875 to 1890 published reports on the geology of the counties within this area. All these reports contain some information in regard to ground water, and they have been freely consulted in the preparation of this report. The United States Geological Survey has published a number of geologic folios covering parts of this area, and they likewise have contributed greatly to this report. In addition to these, many other publications have offered data which have been freely used.

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FIELD WORK

The field work forming the basis of this report was done during the summers of 1928 and 1929 and covered a period of more than 8 months. Well drillers were interviewed, and detailed information was obtained about wells they had drilled. Private owners, both domestic and industrial, were consulted about their water supply. Village, borough, and city supplies were also investigated, no attention being given to those utilizing stream or lake water. The data consist of well logs, measurements of well depths, water-table depths, yield, drawdown, temperature, and other related conditions. About half of the time spent in the field was devoted to the study of the glacial deposits, the preglacial drainage, and those "hard rock" formations that produce water.

Samples of water from wells and springs were collected, and for the purpose of comparison, a few streams were also sampled. These waters were analyzed in the laboratories of the Geological Survey at Washington, D. C., by Margaret D. Foster, S. K. Love, and W. L. Lamar.

The investigation was conducted under the general direction of O. E. Meinzer, geologist in charge of the Division of ground water of the United States Geological Survey.

Were it not for the hearty cooperation of the many well drillers and well owners in the area, this report would not have been possible. Much credit is also due to the various men connected with public water supply companies for their willingness to give freely the information requested. The writer wishes to express his appreciation especially to Mr. C. H. Young, district engineer of the Pennsylvania Department of Health, Meadville, Pa., and to Mr. F. R. Layng, assistant chief engineer of the Bessemer & Lake Erie Railroad, Greenville, Pa., for their cooperation and continued interest in the work. Space does not permit the mention here of the numerous workers whose publications have been consulted freely in preparation of the text. They will be acknowledged in footnotes throughout the report.

CLIMATE

PRECIPITATION

The average annual precipitation in the area at 21 United States Weather Bureau stations ranges from 33.52 to 46.30 inches; the average for all stations is 41.1 inches. (See fig. 2.) The stations of higher altitude, in general, have the greater precipitation, though the stations of less altitude are located near bodies of water, such as the Ohio and Beaver rivers or Lake Erie, and the effect of such bodies of water may account in part for the differences in precipitation.

The wettest weather at most of the stations occurs in June and July, though in the vicinity of Lake Erie October and November are the wettest months. February is the driest month of the year, and November ranks second.

The longest records are those obtained at Erie (altitude 714 feet), which cover 54 years from 1874 to 1927, and at Franklin (altitude 955 feet), which cover 49 years from 1869 to 1927, with 10 years missing. The precipitation at Erie ranged from 55.04 inches in 1878 to 26.43 inches in 1923; at Franklin, from 59.72 inches in 1870 to 31.70 inches in 1900.

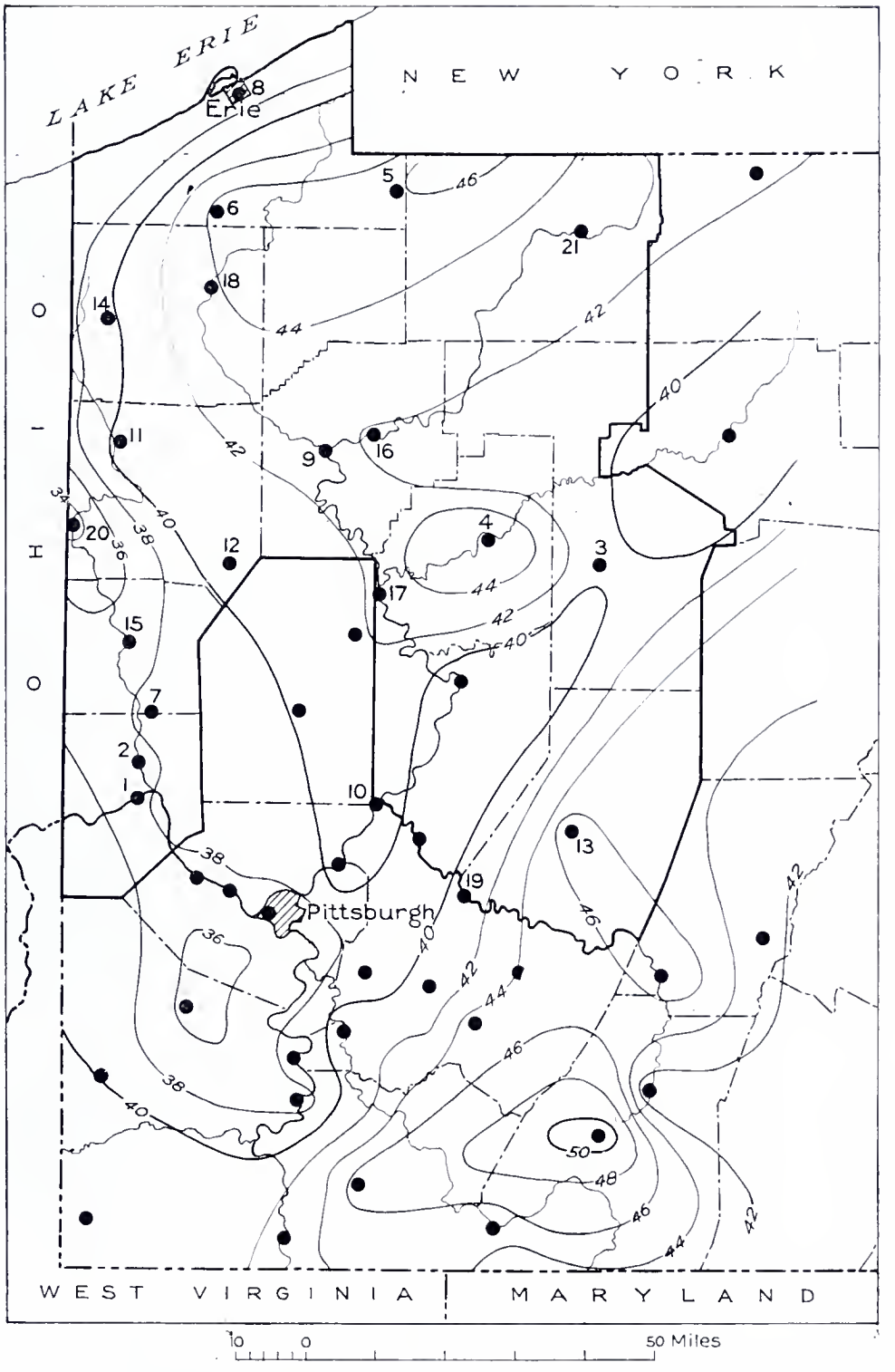


Figure 2.—Map of Western Pennsylvania showing climatologic stations and lines of equal average annual precipitation in inches

Average Monthly Precipitation at 21 Stations in Northwestern Pennsylvania, in Inches

[From U. S. Weather Bureau records]

Station	Altitude (feet)	Length of record (years)	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Beaver Dam	700	35	2.9	2.4	3.4	3.1	3.2	4.7	3.8	3.6	2.9	2.5	2.6	2.8
Beaver Falls	720	20	3.0	2.4	2.6	3.1	3.0	4.3	3.6	3.6	3.3	2.8	2.3	2.7
Brookville	1,173	37	3.3	2.4	3.1	2.8	3.5	4.3	4.3	4.0	3.4	2.9	3.0	3.0
Clarion	1,500	31	3.6	3.0	3.6	3.6	4.0	4.6	4.5	4.1	3.8	3.7	2.9	3.5
Corry	1,410	18	3.3	3.4	3.2	3.4	4.2	5.2	3.4	3.9	4.2	3.9	4.4	3.7
Edinboro	1,212	9	2.6	2.3	3.2	4.0	4.0	4.0	3.8	4.1	3.3	5.2	4.3	3.2
Ellwood City	920	21	3.0	2.3	3.6	3.5	3.2	4.7	4.7	3.8	2.6	2.4	2.3	2.9
Erie	714	54	2.8	2.6	2.7	2.7	3.3	3.4	3.1	3.3	3.5	3.8	3.4	2.8
Franklin	955	49	3.5	2.9	3.4	3.0	3.5	4.6	4.5	3.8	3.7	3.1	3.1	3.4
Freeport	750	51	3.8	3.1	3.6	3.4	3.8	4.4	4.3	3.8	3.1	2.9	3.0	3.4
Greenville	985	31	3.5	2.6	3.5	3.2	3.5	4.0	4.4	3.5	3.6	3.5	3.0	3.0
Grove City	1,256	22	3.3	2.3	3.1	3.5	4.1	4.1	4.3	3.4	3.8	3.4	3.0	3.2
Indiana	1,350	27	3.9	2.9	3.8	3.8	4.4	4.6	4.3	4.4	3.9	3.4	2.8	3.4
Linesville	1,110	15	2.9	2.1	3.1	3.2	3.4	4.0	3.6	3.5	4.0	3.8	3.0	3.4
New Castle	850	41	2.9	2.4	2.9	2.9	3.3	4.4	4.1	3.2	3.2	2.7	2.4	2.6
Oil City	----	24	3.4	3.3	3.4	2.9	3.9	4.8	4.6	3.0	3.6	2.5	3.4	3.2
Parkers Landing	900	42	3.5	3.1	3.5	3.4	3.7	4.3	4.2	4.1	3.4	2.9	3.1	3.3
Saegerstown	1,120	35	3.2	2.9	3.3	3.3	4.3	4.2	4.2	3.9	3.7	3.5	3.5	3.3
Saltsburg	850	35	3.7	3.1	3.2	3.3	3.5	4.3	4.1	3.8	3.6	3.1	2.4	3.3
Sharon	940	16	2.4	1.7	2.7	2.9	3.1	3.6	3.5	3.5	3.1	2.9	2.4	2.4
Warren	1,180	40	2.8	2.6	3.1	3.4	4.2	4.4	4.6	4.1	3.8	3.4	3.5	3.1
Average	----	----	3.2	2.7	3.2	3.3	3.7	4.3	4.1	3.7	3.5	3.3	3.0	3.1

Figures 3 and 4 show graphs of some of the tabulated data.

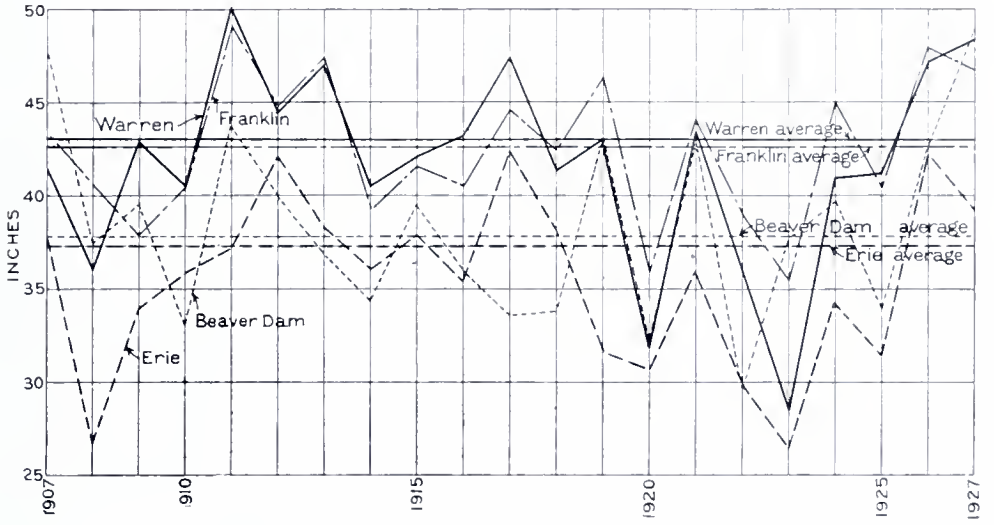


Figure 3.—Annual precipitation at four stations in Northwestern Pennsylvania

Figure 4 shows that for any one month the precipitation may vary greatly from year to year. For example, at Warren during November 1927 the precipitation exceeded the average for that month by almost 6 inches. The annual precipitation also may vary greatly from year to year.

TEMPERATURE

The average mean annual temperature at 12 stations in the area is 48.6° F. In general, the northern stations have a lower mean annual temperature, though at Erie and to a lesser extent at Warren the moderating influence of near by bodies of water seems to be effective. January and February are the coldest months, and July is the hottest. The following table gives the details for the 12 stations.

FROST

The average length of the growing season ranges from 193 days at Erie to 113 days at Brookville. Erie, though the most northern station, has the longest frost-free period, probably because of the moderating influence of Lake Erie. Warren and the stations along the Beaver and Ohio rivers are probably somewhat similarly affected by the nearby streams. The following table gives frost data at 12 stations in the area:

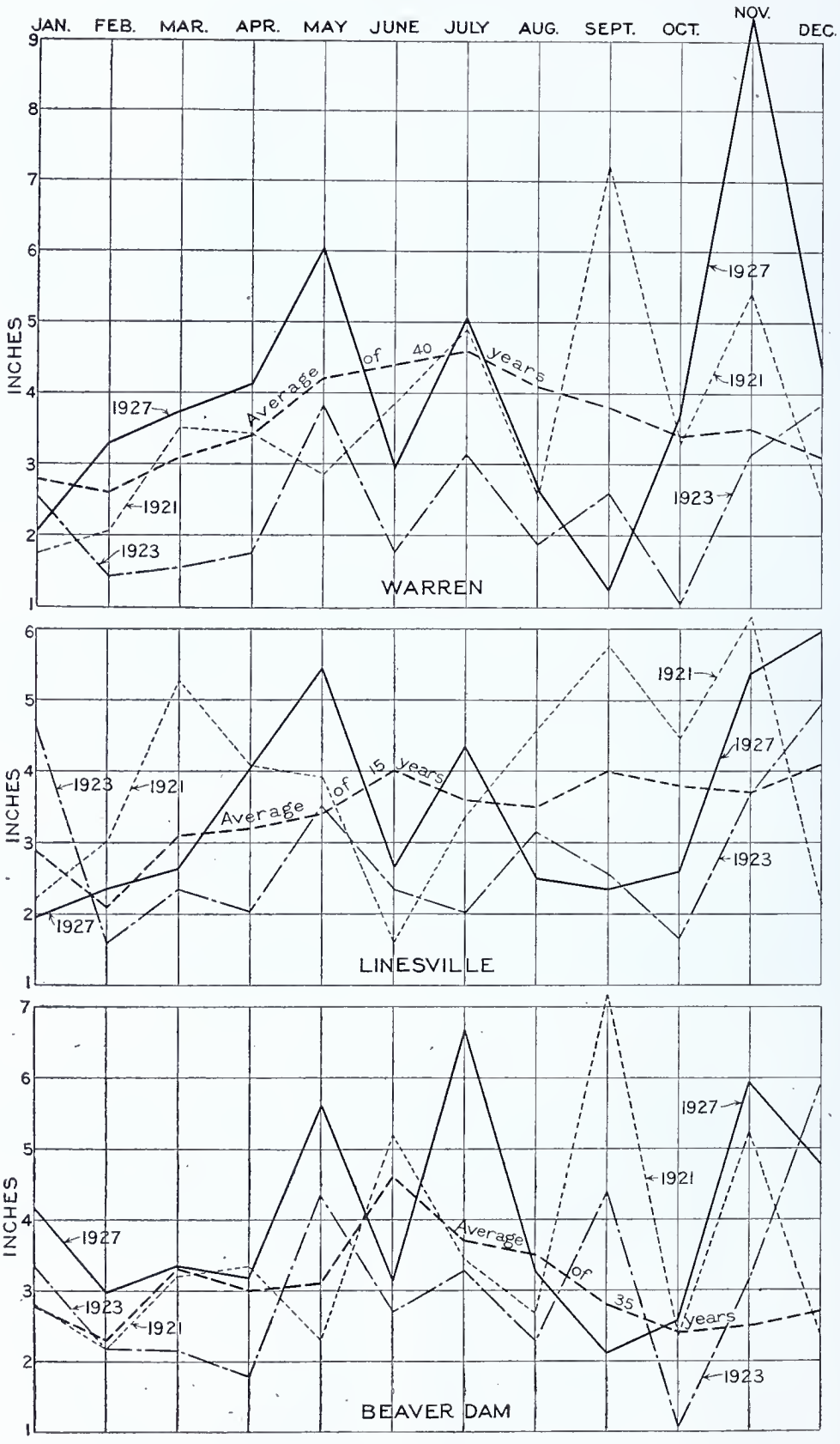


Figure 4.—Monthly precipitation for three years at three stations in Northwestern Pennsylvania

Average Mean Monthly and Annual Temperature (°F) at 12 Stations in Northwestern Pennsylvania

[From U. S. Weather Bureau records]

Station	Altitude (feet)	Length of record (years)	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Beaver Dam	700	14	29.9	32.9	41.1	49.5	60.3	69.2	73.8	72.1	66.4	55.3	43.5	33.1	52.3
Brookville	1,173	15	24.1	25.2	33.6	45.1	55.5	63.2	67.8	66.0	60.0	49.2	37.6	27.9	46.5
Corry	1,410	14	23.8	26.5	32.8	44.5	54.2	64.8	67.2	65.2	60.1	47.0	38.7	29.2	46.2
Erie	714	54	27.2	26.2	34.0	45.0	56.5	66.1	71.3	69.5	64.0	52.8	41.4	31.6	48.8
Franklin	955	33	26.2	25.4	35.8	46.2	57.5	65.6	70.4	68.0	62.6	51.0	39.6	29.3	48.2
Greenville	985	32	26.9	24.9	36.4	46.3	57.7	66.0	70.6	68.6	63.2	50.4	39.6	30.1	48.4
Grove City	1,256	20	26.9	27.5	37.2	47.5	57.6	65.3	70.0	61.5	63.5	51.4	40.4	29.7	48.2
Indiana	1,350	26	28.8	29.2	38.9	49.9	60.0	67.4	71.4	70.0	64.5	52.2	41.1	30.9	50.4
New Castle	850	45	27.8	28.8	36.8	48.8	59.6	68.8	72.4	70.3	64.3	52.0	40.0	30.2	50.0
Saegerstown	1,120	34	24.6	22.8	34.5	45.2	56.2	64.7	68.7	66.8	61.5	50.2	38.6	28.7	46.9
Sharon	940	8	26.9	30.2	38.9	48.9	58.6	68.2	72.6	69.8	66.1	52.0	42.4	31.4	50.5
Warren	1,180	31	25.1	24.2	34.3	44.7	56.1	64.5	69.5	67.4	61.9	50.3	39.1	28.1	47.1
Average	----	----	26.5	27.0	36.2	46.8	57.5	66.2	70.5	67.9	63.2	51.2	40.2	30.0	48.6

Frost Data for 12 Stations in Northwestern Pennsylvania

[From U. S. Weather Bureau records]

Station	Altitude (feet)	Length of record (years)	Last killing frost in spring		First killing frost in autumn		Frost-free period (days)		
			Average date	Latest date	Average date	Earliest date	Shortest recorded	Average	Longest recorded
Beaver Dam	700	12	May 6	May 27	Oct. 17	Oct. 7	135	162	186
Brookville	1,173	16	May 27	June 24	Sept. 17	Aug. 23	91	113	145
Corry	1,410	7	May 24	June 4	Sept. 23	Sept. 12	104	121	146
Erie	714	41	April 21	May 18	Nov. 1	Oct. 9	154	193	225
Franklin	955	30	May 14	June 12	Oct. 5	Sept. 10	121	143	177
Greenville	985	26	May 17	June 17	Oct. 3	Sept. 14	96	139	175
Grove City	1,256	20	May 18	June 17	Oct. 1	Sept. 11	96	136	169
Indiana	1,350	23	May 10	June 10	Oct. 2	Sept. 11	96	145	177
New Castle	850	22	May 9	May 31	Oct. 5	Sept. 14	118	148	180
Saegerstown	1,120	33	May 22	June 17	Sept. 27	Sept. 10	85	128	163
Sharon	940	13	May 2	May 30	Oct. 6	Sept. 15	124	159	195
Warren	1,180	31	May 18	June 24	Oct. 4	Sept. 10	90	139	173

GEOMORPHOLOGY

MAJOR FEATURES

Most of northwestern Pennsylvania lies within the Appalachian Plateaus province. In figure 5 the area covered by this report is subdivided into sections, according to modifications of a map showing physical divisions of the United States prepared by Fenneman.[1] The glaciated section in the northwest corner of the State includes the area that has been markedly affected by glaciation. The southeastern boundary of this section coincides in a rough way with the Wisconsin glacial boundary. The northwestern boundary of the Allegheny Mountains section is placed approximately along the line where the first prominent rock folds begin. In places this line is well defined by Chestnut Ridge, but in the northern part of the State it is more or less obscure. Chestnut Ridge is well defined in Indiana and Jefferson counties, where it trends northeast, and enters Clearfield County at about the southeast corner of Jefferson County. The Allegheny High Plateaus and the Pittsburgh section have considerable relief and are maturely dissected.

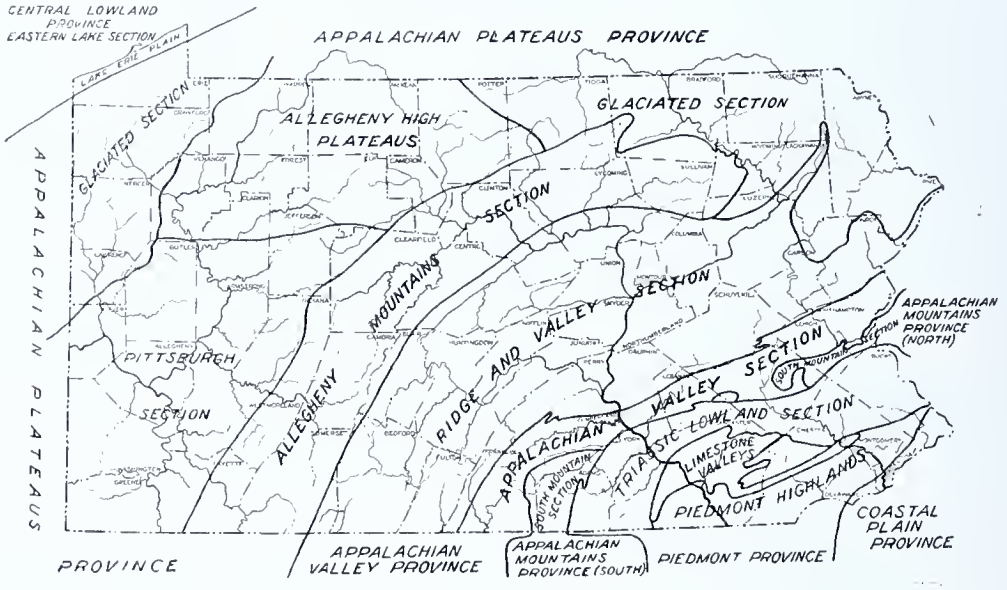


Figure 5.—Physiographic divisions of Pennsylvania (after Fenneman)

Except for a small area along Lake Erie and a still smaller area in the northeastern part of Indiana County, all of the area covered by this report is drained by the Ohio River and its tributaries. The divide between the St. Lawrence River and Mississippi River drainage basins is low and lies only a few miles back from the shore of Lake Erie. (See plate 4.) The Allegheny River, together with its tributaries, drains the largest part of the area. Its major tributaries in the

[1] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 18, no. 4, 1928.

northern counties are French Creek, Oil Creek, and Tionesta Creek, and in the southeastern counties, the Clarion River, Redbank Creek, Mahoning Creek, and the Kiskiminetas River. The western part of the area is drained by the Beaver River and its tributaries, chiefly the Shenango River and Neshannock Creek.

The area covered by this report has a relief of more than 1,600 feet. The lowest part lies along the shore of Lake Erie and has an altitude of 573 feet above sea level. The highest parts lie in the eastern part of Warren County and in the southeastern parts of Jefferson and Indiana counties, where altitudes of more than 2,200 feet are reached. The relief of most of the counties is about 1,000 feet, but Indiana County has about 1,400 feet, and the three southwestern counties have about 700 to 800 feet.

Many of the valleys in the glaciated section have broad, flat flood plains composed of glacial outwash on which the streams meander. In places the valley sides rise rather abruptly from the edges of the flood plain. This is particularly true in the outcrop area of the resistant sandstone of the Pottsville formation. A few miles back from the shore of Lake Erie is a northwestward-facing escarpment made by the relatively resistant Chemung formation. Near the New York State line this escarpment rises at least 400 feet in 1 mile. When traced westward it flattens out and becomes less prominent. (See fig. 6.) The

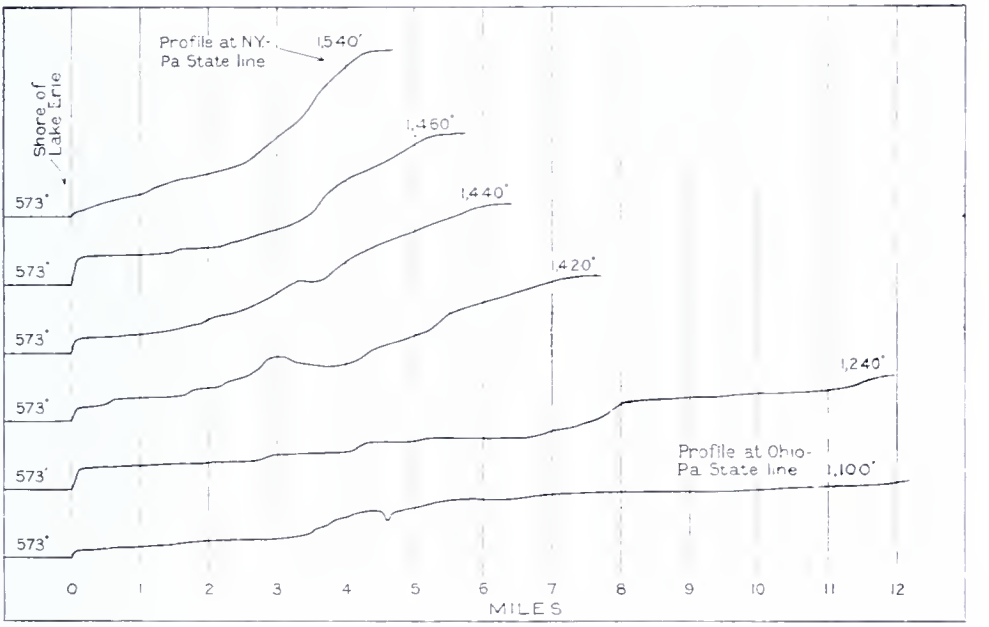


Figure 6.—Profiles of Lake Erie escarpment in Northwestern Pennsylvania

small streams flowing into Lake Erie have cut valleys as much as 200 feet deep in crossing this escarpment. The shore of Lake Erie in places is marked by a cliff standing 125 feet above the lake. It is composed mainly of glacial drift, though in many places bedrock crops out at or somewhat above lake level. Numerous swamps and small lakes occur in the drift-covered section along the old valleys that have been partly filled with glacial outwash.

South of the glacial boundary the surface is more maturely dissected than to the north. The valleys are deeper and have steeper sides, and the areas between the larger valleys are minutely cut up by small tributaries. This region is one of sloping surfaces, there being only small tracts of nearly flat land along some of the valley bottoms and on the uplands.

These upland flats are thought to represent remnants of old erosional surfaces, or peneplains, which were formed long ago. The streams at that time had reduced the area essentially to a plain that lay but a short distance above sea level. On this plain stood small areas of higher land that had not been eroded, either because of their greater resistance or because of their location with respect to the sites of active erosion. Had the process of peneplanation continued longer, these higher areas would also have been reduced nearly to the level of the plain. Earth movements interrupted the process, however, and the low-lying plain was uplifted, thus increasing the gradients of the streams and allowing them again to deepen and widen their valleys. In parts of the area this second cycle of erosion appears to have continued without interrupting uplifts until another low-lying plain was produced. This second peneplain, however, was not so widespread nor so well developed as the first one, for the cycle was brought to an end before the completion of the peneplain by another uplift of the region, which once more increased the stream gradients and renewed their active erosion.

Although many flat areas in this part of the State appear to be underlain by resistant sandstones, these peneplaned surfaces, when considered for the area as a whole, cut across both hard and soft rocks and also seem not to be related to the dip of the rocks.

Campbell [2] recognizes remnants of a peneplain, over much of Pennsylvania. This feature he has called the Harrisburg peneplain because it is well developed in the vicinity of Harrisburg, where it is between 600 and 700 feet above sea level. This is the oldest peneplain of which remnants have been recognized in northwestern Pennsylvania. The earth movements that uplifted the Harrisburg peneplain occurred in Tertiary time and were of such a nature as to elevate parts of the erosional surface more than others. The remnants of the old plain that have withstood subsequent erosion are therefore found today at different altitudes. A reconstruction of the old warped surface on the basis of flat-topped summits shows that the greatest uplift took place in Potter and McKean counties, where the upland flats stand about 2,200 feet above sea level (fig. 7.) Remnants of the old warped surface occur at altitudes of 1,300 feet in western Erie County, 1,340 feet in western Armstrong County, 1,300 feet in the vicinity of Pittsburgh, 1,200 feet at the mouth of the Beaver River in Beaver County, and 1,880 feet in the southwestern part of the Warren quadrangle in Warren County.

The younger and less extensive peneplain, remnants of which occur near the major streams and about 100 feet below the Harrisburg, has been named the Worthington peneplain by Butts.[3] Just how extensive this surface was is not certain, for in Clarion County evidence of

[2] Campbell, M. R., Geographic development of northern Pennsylvania and southern New York: Geol. Soc. America Bull., vol. 14, pp. 277-296, 1903.

[3] Butts, Charles, and Leverett, Frank, U.S. Geol. Survey Geol. Atlas, Kittanning folio (no. 115), p. 3, 1904.

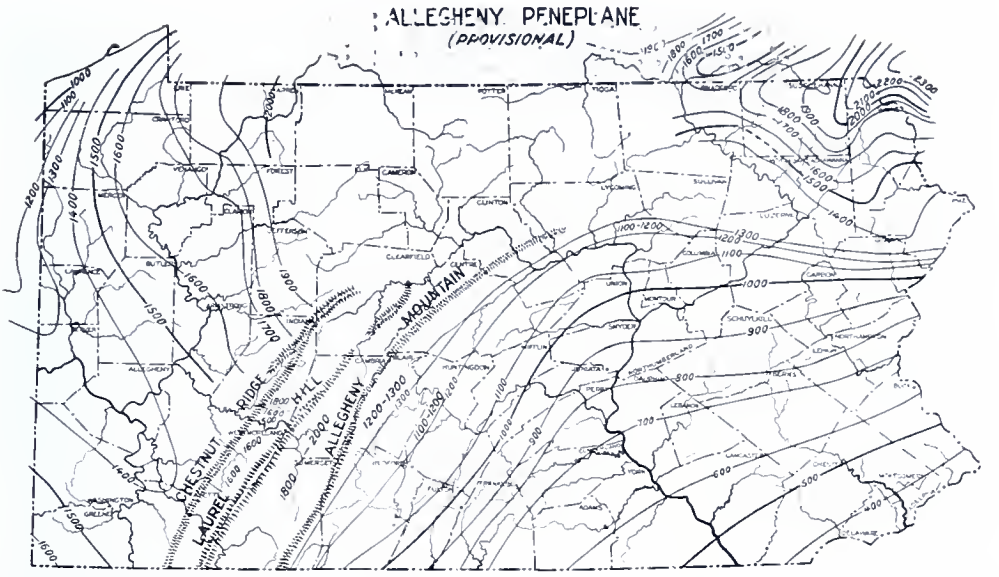


Figure 7.—Map showing restoration of uplifted Harrisburg (Allegheny) peneplain

such an erosional plain is somewhat doubtful.[4] Flat lands that have been considered a part of the Worthington peneplain occur at altitudes of 1,220 feet in the southern part of the Kittanning quadrangle, and 1,360 feet in the northern part, at 1,240 to 1,300 feet in the Rural Valley quadrangle, and at about 1,100 feet in the Beaver and Sewickley quadrangles.

The period of relative quiet that existed while the Worthington peneplain was being formed was brought to an end by an uplift of the land during late Tertiary time. After this movement the main streams entrenched themselves and widened their valley bottoms. However, before this widening process had gone far another uplift occurred, and the streams once more began cutting down their valleys. The remnants of this old valley floor, which has been called the Parker strath, appear now as gravel-covered rock terraces about 200 to 250 feet above the present stream courses.

Most of the major streams flow in entrenched meanders that have steep valley sides. For example, the meandering course of the Clarion River through Clarion County is about 49 miles long, whereas the straight-line course is about 27 miles. These meandering courses have probably been preserved since the time when the streams were flowing with low gradient on the old peneplain, the streams entrenching themselves in their broad meanders as uplift occurred. The sides of the Clarion Valley rise in places about 500 feet above the stream in a horizontal distance of a quarter of a mile. In the southern part of Indiana County, where the Conemaugh River crosses Chestnut Ridge, the steep sides of the valley are more than 1,100 feet high.

PRE-WISCONSIN DRAINAGE

The geomorphic history of northwestern Pennsylvania is very complex, the land forms and drainage pattern being the result of processes that have been operating in the region at least since the uplift of the

[4] Shaw, E. W., Lines, E. F., and Munn, M. J., U.S. Geol. Survey Geol. Atlas, Foxburg-Clarion folio (no. 178), p. 1, 1911.

Harrisburg peneplain, in Tertiary time. Numerous uplifts of the region occurred before the glacial epoch, and depressions caused by the weight of the great ice sheets also took place. The region was partly covered by at least two ice sheets—the Wisconsin and the Illinoian—and possibly by a third—the Kansan or Jerseyan. It is probable that during the time between the advance of the first ice sheet and the retreat of the last different drainage systems existed in this area. Retreats and advances of these ice sheets must have changed the drainage pattern somewhat, as old outlets were closed and new outlets opened and as old valleys were filled and new valleys eroded. It is therefore evident that many complex factors have entered into the drainage pattern as it exists today. It is the writer's opinion that any postulated preglacial drainage pattern is somewhat problematical in the present status of our knowledge. However, because the location and quantity of the ground-water supplies are to a large extent determined by the preglacial and glacial drainage lines, special attention was given to this subject.

The preglacial drainage of northwestern Pennsylvania and southwestern New York was described in detail by Carll [5] in 1880 and by Leverett [6] in 1902. Both these investigators believed that the buried valleys in northwestern Pennsylvania were produced in preglacial time.[7] It probably cannot be questioned that most of the valleys lying outside the glacial boundary are preglacial, but there seems to be considerable evidence supporting the view that many of the buried valleys in the glaciated area originated during glacial time. Plate 1, which shows the present-day drainage pattern of the area, is a pantograph drawing of the streams as shown on United States Geological Survey topographic maps. Most of the streams outside of the glaciated area flow toward the southwest, whereas the dominant stream pattern within the glaciated area is toward the southeast. Plate 2, also a pantograph drawing, shows the pattern of buried valleys within the area. These buried valleys also have a general trend to the southeast. If these valleys are preglacial, then their alignment must have been the result of conditions existing before the advance of the first ice sheet. It seems probable that the preglacial drainage pattern of this area was to a great extent determined by the slope of the land surface after the uplift of the Harrisburg peneplain. It can be seen from figure 7 that the uplifted surface of the Harrisburg peneplain slopes to the southwest in this area. Streams flowing as a consequence of this sloping surface would therefore, in a general way, become alined in a southwesterly direction. This is the trend of most of the streams south of the glacial boundary. The dominant trend of the valleys in the glaciated area is obviously not consequent to the old sloping surface of the uplifted Harrisburg peneplain. Plate 2 shows that most of the buried valleys lie at right angles to the glacial boundary, and for this reason and because the buried-valley pattern does not fit in with the preglacial stream pattern outside of the glacial boundary it would seem to be suggested that the formation of the buried valleys was in some way tied up with glaciation. It therefore seems more logical to

[5] Carll, J. F., Geology of the oil regions of Warren, Venango, Clarion, and Butler Counties: Pennsylvania Second Geol. Survey Rept. I³, pp. 330-397, 1880.

[6] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio Basins: U.S. Geol. Survey Mon. 41, 1902.

[7] Carll, J. F., op. cit., p. 331. Leverett, Frank, op. cit., pp. 89, 135, 237.

assign a glacial age to these buried valleys rather than a preglacial age, as was done by Carll and Leverett. A similar conclusion is reached by Coffey [8] in the northeastern part of Ohio. He concludes that

> Practically all of the deep valleys in this northeast section of the State and probably in other sections as well are of interglacial or postglacial rather than preglacial origin.

That the buried valleys in northwestern Pennsylvania are of glacial origin is further supported by the fact that many of the tributary buried valleys join in such a fashion as to indicate drainage to the southeast, away from the border of the ice sheets.

If it is true that the buried valleys in the glaciated area are of glacial and not preglacial origin, the question arises as to how they were formed by the direct or indirect action of glacial ice. Two possible explanations are apparent—the scouring action of the ice or of subglacial streams along preexisting valleys and the corrasion by water resulting from the melting of the ice sheets.

Ice erosion has taken place to some extent, as is shown by glacial striae both on the uplands and along the slopes of many of the valleys. Small preexisting valleys trending in the general direction of ice movement must have determined to some extent the local direction of ice movement. At Quarry Hill, about 2 miles southeast of Greenville, the Sharon sandstone shows glacial striae that trend about S.37°E., which is parallel with the trend of the Shenango River Valley, to the north, between Greenville and Jamestown (pl. 3, A). However, about 4 miles west of Greenville, near the west side of Big Run Valley, there are glacial striae that trend S.21°E., or nearly parallel to the trend of the valley. Further evidence of the local effect of preexisting topography on the direction of ice movement is offered by an exposure of glacial outwash material about 1 mile southwest of Wesley, in southern Venango County. Here the fore-set beds of sand and gravel dip to the north, in a direction opposite to the general ice movement in northwestern Pennsylvania (pl. 3, B). A tongue of ice appears to have moved a short distance to the north or northeast along a small preexisting valley and at its margin deposited outwash sand and gravel, dipping to the north or northeast.

There appear to be at least three localities in the region under discussion at which the altitude of the bedrock floors of deeply buried valleys is too low to fit into a system of northward-sloping valleys. In other words, there are low points in some of these valleys which apparently could not have been produced by stream erosion and therefore appear to be the result of erosion by the ice or subglacial streams.

A well near Lottsville, in Warren County (No. 339), is an example of one of these "deeps." Carll [9] makes the following statement regarding this well:

> It cannot be questioned, however, that a remarkably deep valley was eroded here, and inasmuch as we have evidences in other places of deep cuttings that seem uncalled for on the theory of regular slopes to old stream beds, it suggests the inquiry whether the under-ice currents, under certain peculiar combination of circumstances, might not be capable of

[8] Coffey, G. N., Preglacial, interglacial, and postglacial changes of drainage in northeastern Ohio, with special reference to the upper Muskingum drainage basin: Ohio Jour. Sci., vol. 30, no. 6, p. 374, 1930.

[9] Carll, J. F., Geology of Warren County: Pennsylvania Second Geol. Survey Rept. I⁴, pp. 234-235, 1883.

> excavating in soft measures to a considerable depth below the level of the main outlet for the subglacial waters.
>
> There appears to have been a time during the glacial period when many of the watercourses were undergoing very active erosion. A new system of drainage was being established under conditions quite different from those which prevailed while the former streams were slowly carving out their beds. The subglacial erosion was not governed by any fixed or steady methods, being necessarily dependent upon the erratic movements of the ice and water upon the surface. It was only at a later period, when the ice began to waste, that the streams were allowed to work out natural gradients for themselves by refilling the old valleys and readjusting the drainage levels.

In connection with the discussion of this well Leverett [10] makes the following statement:

> It is the present writer's opinion that this interpretation [Carll's] may be applicable to this and other valleys in which the remarkably low altitude of the valley floors near the inner border of the moraine have been found.

The valley of Little Brokenstraw Creek, in which this well is located, has a general trend parallel to the direction of ice movement in this area. Again, in Crawford County in the valley of Muddy Creek, which also trends in the general direction of ice movement, a well southeast of Little Cooley penetrated 400 feet of valley filling before encountering bedrock. The altitude of the rock floor at this point is therefore about 800 feet above sea level, which is considerably lower than the altitude of the rock floor either up or down the valley. This appears, therefore, to be another example of a "deep" produced by the scouring action of the ice or subglacial streams.

Leverett [11] describes a well drilled in the city of Meadville which penetrated 475 feet of valley filling before encountering bedrock. The writer obtained reports of this well (well 153) from two separate sources. One of these reports was identical with that of the record published by Leverett, and the other stated that the well was sunk 480 feet without encountering bedrock. The altitude of the rock floor at this well is therefore only about 27 feet above the surface of Lake Erie and is too low to conform with a sloping valley floor in either direction. Leverett concludes that "possibly there was excessive cutting here, such as Carll suggested for the Lottsville gorge." Here again, the trend of the valley is roughly parallel to the direction of ice movement in the region. Coffey [12] mentions a well in northeastern Ohio that appears also to show evidence of glacial scour in a valley roughly parallel to the direction of ice movement. He says:

> A well record southeast of Easton in sec. 21, Chippewa Township, Wayne County, struck rock at 443 feet, and another one near the same place in the NE¼ sec. 20 entered rock at 417 feet. The elevation of the present valley here is about 950 feet, so the rock floor is apparently below the present level of Lake Erie.

Leverett [13] refers to a deep portion in the Mahoning Valley which, it seems, may also be explained as another example of ice erosion. He states:

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[10] Leverett, Frank, op. cit., p. 454.
[11] Leverett, Frank, op. cit., pp. 457-458.
[12] Coffey, G. N., op. cit., 383.
[13] Leverett, Frank, op. cit., pp. 150-151.

In general the slope of the rock beneath the present streams is in harmony with the present drainage and in the main is the reverse of the ancient system. There is, however, a part of the channel in which the rock floor appears to be excavated to a level too low to correspond with the floor at points lower down the stream. Such features were at first

Plate 3



A.—Glacial striae on surface of Sharon sandstone at Quarry hill, about 2 miles southeast of Greenville, Mercer County, Pa.



B.—Fore-set beds of Wisconsin glacial outwash in gravel pit 1 mile southwest of Wesley, Venango County, Pa.

interpreted to signify that the drainage was in the reverse direction from the present line of discharge, but further examination has rendered it probable that the excavation has been accomplished by a stream running in the present line of discharge. On the lower course of the Mahoning the oil-well records show the rock floor to be fully as low as at the mouth of the Beaver and apparently about 90 feet lower than at the mouth of the Connoquenessing, midway of the Beaver Valley and 15 miles below the mouth of the Mahoning. The piers of the railway bridge at the mouth of the Connoquenessing are reported by R. R. Hice, of Beaver, to stand upon the rock floor and are so distributed as to test the middle as well as the border of the valley. Upon passing up the Mahoning a few miles from the deeply excavated part, the rock floor is found to have an altitude nearly 150 feet higher. There is an abrupt descent just above Edinburg. Here the buried floor seems to fall 165 feet in half a mile, as shown by four wells reported by W. H. Raub, of Edinburg. The declivity may be even more precipitous, as the wells are not situated so as to limit more closely the space occupied in the descent. The variations in the valley floor appear to be such as might result from the recession of a fall or cascade, and this suggestion harmonizes with the more clearly indicated history of the region, which appears to be as follows:

Before the ice invasion forced the waters of the upper portion of the Grand River Basin across the divide, which apparently stood near the State line above Edinburg, there was only a small tributary leading down to the valley occupied by the old north-flowing Monongahela system. But when the waters of the upper Grand River Basin were forced over the divide in large volume and descended the steep slope of the little valley, deep scouring at the mouth would naturally result, and the formation of cascades or falls would readily follow. These would work upstream as the erosion progressed. They appear to have reached a point just above Edinburg, when a later incursion of the ice stopped the process and filled the deep valley with debris. The formation of a pool was favored by the softness of the rock in this portion of the valley and the hardness of the strata encountered near the mouth of the Connoquenessing.

It is apparent that the softness of the rock mentioned by Leverett would also be quite favorable in allowing the ice to erode excessively at this point. Butts[14] makes the following statement in trying to explain deep points in the valleys around Warren:

There may be actual depressions of small extent below the general level of the old valley floor, due either to the scouring action of the glacial ice that occupied the valleys before they were filled by detritus, or to decomposition prior to the glacial filling of the rock floor of the old valley; and each of the wells mentioned may be over such a depression. Glacial scour seems the more probable explanation. * * * The main movement of the ice southward must have been along Conewango Valley, and if a preglacial col had existed between Russell and Warren it would have been worn down by the ice, perhaps nearly to the level of the river bed. Thus the present uncertainty regarding the slope of the rock floor and the direction of the preglacial drainage may have been brought about.

Gilbert[15] has emphasized the ability of eroding ice to change the topography of a region. However, he makes the following statement:

Whatever the general potency of glacial ice, a wide variation of local power should be assumed, and the extent to which ice is responsible for the topography of a district is ordinarily a problem to be solved only through the study of local phenomena.

Regarding the area south of Lake Ontario in western New York he concludes that:

[14] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Warren folio (no. 172), p. 9, 1910.

[15] Gilbert, G. K., Glacial sculpture in western New York: Geol. Soc. America Bull., vol. 10, pp. 121-130, 1899.

> The ice left the broad plateau of firm Niagara limestone with little modification. The cliff at its northern edge was somewhat worn but its position not materially changed. The resistant ledges north of the Niagara limestone were worn back so far as to lose the contours typical of subaerial erosion. The topography of the Medina shale was reconstructed, its system of stream valleys and interstream ridges being replaced by glacial fluting on a large scale. While the Niagara escarpment antedates the period of glacial sculpture, ice erosion rendered it more prominent by excavation along its base and by the general degradation of the lowland it overlooks.

In the area underlain by the shale of Medina age the present valleys trend in a direction parallel to the direction of ice movement, as shown by glacial striae. This direction is not controlled by jointing in the region, for the joints trend east and west, nor is it the direction of preglacial drainage, which presumably was about due north into Lake Ontario. Gilbert states:

> If the drift were wholly removed and the rock surface bared, the topography would comprise a series of ridges and troughs running parallel to the trend of the northeasterly streams. The details of rock configuration conform to the direction of ice motion and are evidently products of glacial erosion.
>
> The depth of the furrows is not definitely known, but some of them exceed 40 feet. Measurement was largely dependent on the facilities afforded by surface wells, and these do not completely traverse the drift in the deeper furrows. The significant fact is that throughout a considerable area the preglacial topography, presumably including a system of shallow valleys descending northward, was obliterated, and a radically different system of valleys was wrought. This could hardly have been accomplished without a general reduction of the surface to the extent of 40 or 50 feet, and the amount may have been considerably greater.

It therefore appears that in the glaciated area south of Lake Erie there are several places where the ice locally scoured out valleys which in a general way trended in the same direction as the ice sheet moved, and it is not at all improbable that with more complete data or more detailed study many more examples could be cited. It is by no means contended that all the buried valleys of northwestern Pennsylvania owe their origin to ice erosion. Indeed, it is not contended that any of these valleys were produced entirely by the scouring action of ice. However, the conclusion seems unavoidable that many of these valleys were in places deepened to some extent by the action of eroding ice. If this is true, let us inquire what bearing it has on the criteria used by Carll and Leverett in postulating the direction of former drainage along these buried valleys lying in the glaciated area.

By means of the thickness of valley filling encountered in well borings both Carll and Leverett calculated the altitude of the bedrock floor at different places along the buried valleys. By comparing the altitude of the rock floor at the different bore holes they concluded that the bedrock floor along any one valley slopes in a certain direction, and that therefore the former drainage along this valley was in that direction. This reasoning at first glance appears sound, but on further consideration there seem to be a number of factors that must be calculated before the former drainage can be considered as established in any one direction. These factors are at least three. The first and most obvious factor, in the light of what has been said above, is the deepening of valleys by glacial scour or subglacial streams. It is apparent that if glacial scour has taken place at different times and at different places—

a conclusion that seems unavoidable—the more or less regular profile of a former stream bed would become irregular, with low points below the former profile at those places where ice erosion had taken place. One cannot therefore be certain that the altitude of the bedrock floor at any one boring represents the altitude of the true former profile of the stream or whether the bedrock at that point has been gouged out by glacial action. Only at exceptional places, such as those mentioned above, can it be said with a reasonable degree of certainty that ice erosion has occurred, and even at these places the amount of deepening due to ice scouring cannot be determined. It is therefore not possible to evaluate quantitatively the effect of this first factor.

The second factor that introduces uncertainties into the problem consists of the incompleteness and inadequacy of the well records. At very few places are well records numerous enough to establish with certainty the lowest altitude of the rock floor in that stretch of the valley. In many places the only records available are those of wells that did not encounter bedrock, and therefore, although it is known that the bedrock lies lower than a certain altitude, its true altitude is still uncertain. In places there is evidence that the deepest part of a valley is quite narrow and in other places that the deepest part does not lie in the middle of the valley. In such places it would be rather difficult to ascertain the deepest part of the valley without numerous wells forming a section across the valley. In this connection Carll[16] gives the records of 42 wells in the Conewango Valley from Warren to the State line which show the amount of valley filling. He makes the following statement:

> Mr. Randall undertook the collection of the above facts, hoping to obtain the requisite data for mapping the floor of Conewango Valley, so that the windings of the old stream could be definitely followed in its course northward. But unfortunately for the purpose in view, the oil wells were not confined to the creek flats. From Glade to North Warren the development took nearly a straight line, which carried it east of the valley, so that no light was thrown upon the depth of stream-bed drifts between those points.
>
> A few scattering wells are not to be depended upon in carrying out a design of this kind. They prove a certain depth of drift, but unless a closely connected line is carried completely across the valley there is no certainty that the deepest part has been found. There are no sure rules for marking out an old channel without drilling. Sometimes it may be near the center of the valley, at others quite close to the bluffs on the right or left.
>
> The wells at North Warren seem to indicate that the old floor there is not quite as low as at Warren, but an untested space remains, where a deeper channel might have run—swinging around west of the railroad and curving to the northeast between the wells on the Hiller farm and the Hatch farm. This in a stream flowing northward would not be an unnatural course for it to take, and the shape of the present valley is favorable to it.

Leverett[17] in referring to the records of these 42 wells given by Carll makes the following statement:

> It is Carll's opinion that the wells which show a relatively small amount of drift are not in the deep part of the ancient channel. They are all, however, in the valley bottom, the range in altitude of the well mouth

[16] Carll, J. F., op. cit., pp. 309-310.
[17] Leverett, Frank, op. cit., p. 453.

being from 1,188 feet in Warren to 1,240 feet at the State line, with no wells between whose mouths are more than 20 feet above the level of the one at the State line.

In the following example Leverett appears to have arrived at an erroneous conclusion by attaching too much significance to the altitude of rock floors determined by means of the records of a few scattered wells. In describing the conditions in the vicinity of the present junction of the Allegheny River and French Creek in Venango County, he says:[18]

> At Franklin, in an oxbow filled with early glacial gravel, one boring reached rock at 1,040 feet above tide, and another penetrated to a level only 1,015 feet above tide without reaching rock. * * *
>
> Following the supposed outlet northwestward, there is an old meandering valley lying near the present French Creek and in part coinciding with it. On a small eastern tributary of this old valley 3 miles northwest of Franklin, wells situated a mile or more back from the junction of the tributary with the old valley strike a rock floor at about 1,040 feet above tide, which is about as low a level as the rock floor found in one of the wells in the Franklin oxbow and is within 25 feet of the bottom of the other. These wells penetrate about 100 feet of drift of early glacial age. As they are back from the principal valley, the presumption is that the main channel is lower. Farther northwest along the valley, at a point 8 miles from the Allegheny, a well is found which reaches the rock floor at 1,025 feet above tide—that is, at a depth intermediate between the depths of the two wells in the abandoned oxbow at Franklin. This well is situated near the southern edge of the valley and can scarcely be supposed to have struck its deepest portion. Again, in an old oxbow 3 miles north of Utica, similar in every way to the oxbow at Franklin except that it lies within the limits of the Wisconsin ice invasion, the floor is shown by one well to be 945 feet and by another 960 feet above tide—that is, 70 feet and 55 feet, respectively, below the bottom of the lowest well in the Franklin oxbow. * * *
>
> The evidence seems very strong that the oxbow at Franklin, the old channel northeast of Utica, and the oxbow north of Utica are remnants of the floor of the same old meandering streams leading northwestward. The fact that the rock floor in the oxbow north of Utica is 70 feet below the deepest determination of the old channel where it left the present Allegheny renders it highly improbable, if not impossible, that it was formed by a stream discharging toward the Allegheny. It is even lower than the present rock bottom of the Allegheny, notwithstanding all the erosion the latter is believed to have suffered since the deposition of the early glacial gravels. It is highly probable, therefore, that we have in these abandoned valleys a continuation of the old middle Allegheny.

The writer obtained records of wells between the Franklin oxbow and the oxbow north of Utica which raise considerable doubt as to the northwestward slope of the rock floor between these two points. Wells 416-419 and the two borings that are indicated on plate 4 as having encountered bedrock at depths of 46 and 60 feet all encountered bedrock at altitudes as low as or lower than the two wells cited by Leverett in the oxbow north of Utica. A record of a well in the old oxbow at Franklin shows the bedrock to lie 104 feet below the surface, or at an altitude somewhat less than 1,000 feet, which is about 15 feet less than the lowest altitude cited by Leverett in the Franklin oxbow. Well 414, in the southern part of Franklin, in the Allegheny Valley, shows the altitude of the rock floor near one side of the valley to be about 945 feet above sea level. These more recently obtained well records probably do not disprove or establish drainage in any one direction in this

[18] Leverett, Frank, op. cit., pp. 134-136.

vicinity, but they seem to point to the precariousness of postulating former drainage in any one direction based on the records of a few scattered wells.

The records of future drilling will establish more definitely the deep points in these buried valleys, but in the present state of our knowledge the direction and amount of slope of a bedrock floor based on the records of scattered individual wells, some of which are miles apart, do not seem to be established with much certainty. The second factor is therefore also hard to evaluate at the present time.

The third factor open to question is the method of obtaining accurate altitudes on the rock floor at the different wells. Since the publications of Carll and Leverett a considerable amount of accurate leveling has been done in northwestern Pennsylvania which has shown that the altitude assigned to some of the old bench marks was in error as much as 15 feet. Leverett[19] makes the following statement regarding altitudes in this area:

> The following table of altitudes along the portion of the moraine in Ohio and Pennsylvania is based largely upon barometric readings, but few accurate levels being available.

The altitudes of the tops of many of the well casings were presumably barometric determinations run from these old bench marks. The inaccuracies of barometric leveling, in addition to the errors in the altitudes of bench marks as mentioned above, seem to leave some doubt as to the amount and direction of slope of some of the old bedrock floors, which in one area was reckoned as about 20 inches to the mile.[20]

In addition to the above mentioned uncertainties regarding the direction and amount of slope of the old gradation plains, there is also the possibility that these old gradation plains have been affected by regional earth movements. In discussing the slope of the gradation plain along the Beaver Valley, Leverett[20] says: "This slope has possibly been made greater by Pleistocene changes in level, though specific evidence is not at hand."

There is still another factor that must be properly evaluated when used as a criterion for determining the direction of former drainage. This is the significance of narrow portions of a valley lying within the glacial boundaries. A narrow stretch of a valley bordered by highlands of greater altitude than the highlands adjoining the valley, either up or down stream from the narrow stretch, at once suggests the possibility that at one time a drainage divide existed at or near the narrow place and that for some reason or other the stream has been made to cross this earlier divide and establish drainage in the opposite direction beyond the divide. It must be borne in mind, however, that other conditions may be the cause of a narrow stretch of a valley. In many parts of northwestern Pennsylvania the bedrock into which valleys have been cut is extremely variable in composition. The bedrock of the area therefore exhibits a wide range of resistance to erosion, and as a result many narrow, steep valleys have been produced at certain places. Beyond the glacial boundary many of the valleys have narrow stretches that presumably are the result of the unequal resistance of the bedrock to erosion at different places. Such a condition has therefore been produced in parts of northwestern Pennsylvania without the

[19] Leverett, Frank, op. cit., p. 439.
[20] Idem, p. 150.

aid of glaciation. Narrow places in valleys within the glaciated area do not therefore necessarily indicate a reversal of drainage. Leverett[21] makes the following statement regarding the Ohio River Valley:

> The variable resistance offered by the rock formations has produced an appreciable effect on the size of the valley. It ranges in width from less than a mile up to 5 or 6 miles and in depth from scarcely 100 feet up to about 800 feet. It is narrow in the deep portions as well as in its passage across hard or resistant rocks, and broad in the shallow portions, which are generally excavated in shales or other soft or easily disintegrated rocks. Where the rocks are very easily disintegrated the uplands are greatly broken down for some distance back from the immediate bluffs of the stream, thus giving the valley the appearance of being smaller than it really is; but a full restoration of the original surface in these soft formations would require decidedly more filling than in the hard formations.

Although recognizing the effect of the varying resistance of the bedrock in producing wide and narrow portions in a valley, Leverett appears to attach considerable significance to narrow portions of a valley as indicating places where a divide formerly existed. Thus he postulates that the Allegheny River has been diverted across a col about 8 miles south of Irvine, near Thompsons station (now Althom), chiefly because here the valley is narrow and bordered by highlands of greater altitude than the highlands either up or down stream.[22]

Butts,[23] however, expressed a different opinion, saying:

> It has been generally held that there was a preglacial col in the vicinity of Thompsons, a few miles southwest of the quadrangle. This col, if it existed, blocked all drainage southward along the Allegheny and compelled it to go northward, joining the old Tionesta at Irvineton or Warren, whence its only possible outlets were by the Conewango or the Big Brokenstraw.
>
> The third outlet, that along the present Allegheny, was of course impracticable if the col at Thompsons station really existed. The argument for it is the narrowness of the Allegheny Valley for several miles in this part of its course. It is clearly much narrower than it is north and east of Thompson station to Warren or south of it to Tidioute. The fact that the rocks constituting the Venango oil-sand group form the bottom and lower walls of the valley in this narrow part should be taken into consideration in interpreting the meaning of the constriction. This zone of rocks contains a number of sandstones and conglomerates that are more resistant than the rocks higher up the river or lower down, and the probable difference in their resistance to erosion may account for the difference in the width of the valley.
>
> So far as known to the writer, no determinations of the elevation of the rock floor have been made in this part of the valley, so that the possibility that the preglacial drainage may have gone southward along the present river valley is not disproved by any positive evidence, and as the river valley in this part is no narrower than in the Conewango Valley just north of Warren or the Big Brokenstraw Valley at Irvineton, if as narrow, it appears to the writer at least quite as probable that the preglacial drainage followed the present Allegheny Valley as that it followed either the Conewango or the Big Brokenstraw.

In view of the fact that many of the streams in the unglaciated area have eroded valleys that are wide or narrow, depending on the resistance of the bedrock into which the valleys have been cut, it would

[21] Leverett, Frank, op. cit., p. 84.

[22] Leverett, Frank, Report of the committee on sedimentation, 1928-29, pp. 89-91, Nat. Research Council, 1930.

[23] Butts, Charles, U. S. Geol. Survey, Geol. Atlas, Warren folio (no. 172), pp. 9-10, 1910.

seem that such features in the glaciated area do not invariably indicate old drainage divides that have been cut through by changes in glacial drainage.

Leverett[24] has indicated several probable lines of northward drainage to Lake Erie. A careful study of valleys in Erie County, together with well records and the relations of these valleys to the bedrock escarpment facing Lake Erie, has led to the conclusion that only one former line of drainage northward into Lake Erie in Pennsylvania is indicated by the field evidence. This line of drainage is shown on plate 4 as extending along Conneaut Creek from Conneaut Lake nearby to Albion and thence following the course of Crooked Creek to Lake Erie a few miles east of the Pennsylvania-Ohio State line. As shown by well records or rock outcrops, all the other valleys in the central and eastern part of Erie County, when traced northward toward Lake Erie, are underlain by bedrock at such an altitude that no former northward drainage across Erie County to Lake Erie seems possible.

The buried-valley pattern in the glaciated area as shown on plate 2 is rather difficult to explain in detail. It appears to be related in some way to the glacial boundary either at the maximum extent of the ice or at some temporary position of the ice margin during either advance or retreat. To the writer it appears most likely that the buried valleys were eroded during one or more of the stages of glaciation by the waters that drained away from the margin of the melting ice. If such valleys were formed during Illinoian or pre-Illinoian time they necessarily were greatly affected by the Wisconsin glaciation, either by ice erosion or by water erosion resulting from the melting of the Wisconsin ice. Obviously such an interpretation applies only to those buried valleys lying in the glaciated areas in northwestern Pennsylvania and is not intended to apply in the regions beyond the glacial boundary where there appears to be well-established evidence for the drainage changes postulated by Leverett. The northward drainage through the Beaver River Valley and Conneaut Creek Valley also seems established.

GEOLOGY

SURFACE DEPOSITS

RECENT ALLUVIUM

In recent times silt, sand, and gravel have been deposited along the valley bottoms by the streams during flood stages. Along those streams that flow in narrow V-shaped valleys very little alluvium is present, but in the broad, open valleys flood waters may extend considerable distances back from the normal stream channels and there deposit sediments. With successive floods this alluvial material is picked up and redeposited in other places, and this natural process of sorting tends to bring together the coarser materials at the places where stream velocities are greatest and the finer silt in the slack-water portions of the stream. However, the sites of greatest stream velocity are not always the same during different floods, and in this way layers of coarse and fine material may be built up one above the other. The ever-changing movement of flood-plain material is indicated by the change

[24] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio Basins: U. S. Geol. Survey Mon. 41, pp. 137-140, 1902.

in shape or even complete disappearance of river islands after floods, as well as by the appearance of new islands and the shifting of entire river channels.

PLEISTOCENE

GLACIAL DRIFT

General features.—Some of the pebbles, cobbles, and boulders on the surface of the glaciated section of northwestern Pennsylvania (fig. 5), are unlike any of the native rocks that occur in that region. They are chiefly granites and other igneous rocks that do not occur locally as bedrock but are similar to rocks that are exposed to the north in Canada. These igneous rocks have been carried to their present position by the great ice sheets that moved down from Canada and covered parts of the northern United States. Many of these igneous boulders, or "erratics," as they are called, have flat faces on which can be seen parallel scratches or striae. In places the sandstone and limestone bedrock is also striated. The thick ice sheet moving from the north froze on to the loose rock debris that lay on the surface, plucked off large masses of the rock over which it was passing, and with these materials frozen in its lower parts planed off and scratched the bedrock surfaces. As the ice melted, the rock material frozen in the glacier was deposited, some of it directly with no sorting by water, and some of it carried long distances from the ice margin by run-off waters from the melting ice. The former is called "till," the latter "outwash" and the two together are spoken of as "glacial drift." Whenever there was a halt in the retreat or advance of the ice front, deposits accumulated near the edge of the ice and moraines were built up.

In the Mississippi Valley region glacial drift of five separate ice sheets has been recognized. They are distinguished from one another on the basis of their topographic expression, degree of weathering, and relations to interglacial deposits. The following is the classification of the glacial or Pleistocene series:

Wisconsin glacial stage (youngest).
  Peorian interglacial stage.
Iowan glacial stage.
  Sangamon interglacial stage
Illinoian glacial stage
  Yarmouth interglacial stage
Kansan glacial stage
  Aftonian interglacial stage
Nebraskan glacial stage (oldest).

After each invasion the ice melted back far to the north. The advances and retreats of the ice margin took many centuries, and the movement was in general not continuous but rather a combination of oscillations back and forth which over a long period of time resulted either in a general advance or retreat of the outer margin of the glacier. During the interglacial stages vegetation sprang up on the newly formed drift sheet, and stream erosion and soil weathering again became operative.

In northwestern Pennsylvania the drift sheets of only the Wisconsin and Illinoian invasions are present. Where the Wisconsin ice did not extend as far south as the Illinoian, the Illinoian lies at the surface

and the amount of weathering is greater than that of the Wisconsin, for it has been exposed to weathering processes much longer than the Wisconsin drift. The outer portions of the pebbles of the Illinoian drift have become disintegrated or "rotten," whereas the Wisconsin pebbles have smooth, fresh surfaces. Near the mouth of the Beaver River, in Beaver County, and near Clarendon, in Warren County, occur high-level gravel deposits that Leverett[25] believes to be pre-Illinoian. At several places south of the generally recognized glacial boundary erractic boulders have been found in such topographic positions that they seem not to be related to the drainage from the Illinoian ice. Leverett[26] suggests that these erratics may be erosional remnants of an old drift sheet, possibly of Kansan age.

The glacial boundaries, or lines marking the greatest southern extension of the Wisconsin and Illinoian ice sheets, are shown on plate 4.

Till.—As till is glacial drift that has been dropped directly from the melting ice without appreciable handling by water, it is unassorted. The ice contained material ranging in size from fine clay up to boulders several feet in diameter. A well driller in Crawford County, for example, reports striking a boulder at a depth of 8 feet which caused him to abandon the hole. In the second hole, about 9 feet away from the first, he struck the same boulder at a depth of 9 feet. With each blow of the bit on the boulder in the second hole, the boulder in the first hole could be seen to move. The third hole, about 20 feet from the other two, did not encounter the boulder. The till is composed of more or less coarse material with the intervening spaces filled with finer particles. The coarse material may make up a high percentage of the till or may be almost completely absent. The till of northwestern Pennsylvania is in general more or less gravelly or stony. Where it is exposed in many of the road cuts, it has the appearance of ordinary gravel. However, if the outer portions of the exposure, from which the fine material has been washed, are removed the typical heterogeneous relation of the fine and coarse material is apparent. This gravelly till of northwestern Pennsylvania is in contrast to the dense clayey till of much of the upper Mississippi Valley.

Outwash.—The melting of great thicknesses of ice produced large quantities of water, which flowed away from the ice margin. Some of the loose debris released by the melting ice was picked up or rolled along by these currents of water and transported to greater or lesser distances from the ice edge. These run-off waters flowed in the valleys that already existed—in some valleys in the opposite direction to the normal stream gradients—but in some places they were forced to make new channels. In the valleys with gradients sloping in the opposite direction to the movement of the glacial streams long, narrow lakes were formed, and in these ponded bodies of water great quantities of material were deposited.

The position of the ice edge and the rate of melting changed from time to time, and therefore the sites of deposition of coarse and fine materials shifted. In this manner gravel was deposited on silt, and sand on gravel, or any other possible succession of sediments.

[25] Leverett, Frank, Report of the committee on sedimentation, 1926-27, p. 46, Nat. Research Council, 1927.
[26] Personal communication.

In part of the glaciated area the covering of drift is so thick that some of the old valleys are completely filled, and the presence of such valleys is shown only by well borings. This condition appears to occur in parts of Mercer County. Many of the valleys of the area, however, were only partly filled, and these remain at the present time as steep-walled, flat-bottomed valleys in which sluggish meandering streams flow. The thickness of this valley filling is 300 feet or more in many places, and in a few well borings almost 500 feet is recorded.

In the region south of the glaciated area the valleys were partly filled with outwash material for considerable distances south of the glacial boundary. However, since the retreat of the last ice sheet erosion along these valleys has been active and has removed much of the outwash. The portions remaining stand as terraces at different altitudes above the streams. The high terraces of this area have been well described by Shaw,[27] who says:

> The terraces of the Allegheny and Ohio are almost continuous from the mouth of the Clarion to Pittsburgh and on down the Ohio. The gravel deposits on them are thin or absent where crossed by lateral streams, in other words, where erosion has been most severe—but enough remains to indicate clearly the position of the original upper surface. At over 100 places the upper limit of gravel has been determined by level, and that limit is in all cases very nearly 300 feet above present low water. The elevation of the rock floor beneath the deposits has also been determined at many points and is found to be a little less than 200 feet above the present position of the rivers. Thus, the upper limit of gravel falls regularly from 1,145 feet at Foxburg to 1,010 feet at Pittsburgh, the rock floor beneath the gravel from 1,015 to about 880 feet, and the river from 845 to 700 feet. Here, then, are three approximately parallel planes, each of which slopes about 140 feet in 80 miles. In other words, the gravel formation holds its thickness of about 125 feet and slopes in the direction of present stream flow.
>
> The pebbles are well rounded and lie in a matrix of sand and clay, though in some places there is so little fine material that the gravel is dug from pits and used without further washing. In such places beds of gravel are separated by lenses of clay, but on the whole the formation is homogeneous.

CARMICHAELS FORMATION

In the region south of the glacial boundary some of the valleys contain terrace gravel, sand, and clay that are similar in every way to the materials of the ordinary glacial terraces except that they contain no pebbles of igneous rock. These materials occur only in the valleys that did not carry drainage from the melting ice sheets. These deposits are known as the "Carmichaels formation" and were thought to be of Kansan (?) age. However, Leverett[28] now believes that the main deposits of high glacial gravel in the valleys of the Beaver, Allegheny, and Ohio Rivers are of Illinoian age. Shaw[29] has shown that near Foxburg the Carmichaels formation is intermingled with the glacial gravel and implies that they are contemporaneous. The Carmichaels formation is therefore of Illinoian age if Leverett's interpretation is correct. The formation attains a thickness of 120 feet in places but in most

[27] Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. Geology, vol. 19, pp. 140-156, 1911.

[28] Leverett, Frank, Report of the committee on sedimentation. 1926-27, p. 46, Nat. Research Council, 1927.

[29] Shaw, E. W., Lines, E. F., and Munn, M. J., U.S. Geol. Survey Geol. Atlas, Foxburg-Clarion folio (no. 178), p. 8, 1911.

localities is much thinner. Shaw[30] makes the following statement relative to the Carmichaels formation along the Clarion River:

> The Clarion gravels are much like those of the Allegheny, but differ from them in the following respects: First, the material is of local, not glacial, origin. Second, the thickness decreases upstream. Third, the gravels are as a whole much finer, only the base being as coarse as the glacial gravels. There are some minor points of dissimilarity, but these are the important ones in the present discussion.
>
> In present distribution the gravels are as continuous as those of the Allegheny. There is scarcely a halfmile of the lower part of the valley where they are absent or even approximately so.
>
> That the Clarion terraces are of stream origin is shown by characters similar to and as decisive as those of the Allegheny terraces mentioned above, and certain important features indicate the immediate cause of the accumulation of gravel. First, at the confluence of the two rivers the high-terrace gravels correspond exactly in elevation and thickness. Second, the Clarion gravel rises and becomes thinner and narrower upstream, and at a distance of 20 miles from the Allegheny the formation has the width, thickness, and coarseness of an ordinary flood-plain deposit.
>
> These facts suggest at once that the Clarion terraces owe their existence to conditions on the river into which that stream discharged. When the Allegheny began to aggrade, the effect was that of a gradually growing dam across the mouth of the Clarion. This caused the latter stream to drop the coarsest part of its load. The dam did not grow so rapidly as to produce a pond in the river above, but aggradation kept pace with the growth of the dam. In other words, at its mouth the Clarion built up as rapidly as the Allegheny. This is shown by the ever downstream dip of the Clarion gravels, and by their coarseness. If any ponded stage had existed the deposit would have been coarse only at the upper end of the pond and would have taken the form of a delta.
>
> But of course the dam did not affect the Clarion throughout its length. On the contrary, when the dam began to grow, its influence was felt only in that part of the stream immediately above. As it grew the area affected by it extended farther and farther from the Allegheny and the river built up to a new gradient, over which it was just able to carry its normal load. The coarser part of the gravel was dropped where the gradient changed from the old to the new. This point gradually moved upstream and the extended coarse deposit became the basal coarse part of the formation. The Clarion then silted up because its master stream—the Allegheny—was aggrading, and the elevation of its outlet was being raised. The Allegheny aggraded because of great increase in load, the Clarion because of decrease of gradient.
>
> The work of the Clarion may be taken as a type of the work of those streams which discharged into the overladen Allegheny and Ohio. Redbank Creek, the Conemaugh, Kiskiminetas, Youghiogheny, and Monongahela show similar characters. On all except the smallest of the tributaries of the Allegheny there are deposits connecting with the early glacial valley train, such deposits rising, thinning, and narrowing upstream and consisting of mixed coarse and fine material of local origin, the proportion of fine being somewhat greater than in the valley train. The larger the tributary the more gradually does the deposit rise and thin, for the larger streams have less fall, and there is less difference between the old gradient, with which the streams were more than able to carry their loads, and the adjusted gradients, with which the streams did neither cut nor fill.

[30] Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. Geology, vol. 19, pp. 146-148, 1911.

ROCK FORMATIONS

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

General features.—The Pennsylvanian series is divided into four formations on a more or less arbitrary basis. The Pottsville formation —the lowest of the four—rests unconformably upon the underlying Mississippian and is predominantly sandy or conglomeratic. The Allegheny formation lies comformably upon the Pottsville and because of its workable coal beds is the most valuable economic formation in the area covered by this report. In the early geologic reports on Pennsylvania this formation was called the "Lower Productive Coal Measures." Above the Allegheny and conformably on it lies the Conemaugh formation. There are in places minor unconformities between the two formations, but they appear to be only locally developed. Formerly this formation was known as the "Lower Barren Coal Measures." The highest formation of the Pennsylvanian series is the Monongahela, which is conformable on the Conemaugh. It is of great economic value in southwestern Pennsylvania but is present only on the higher lands in the southern part of the area covered by this report. To the early workers it was known as the "Upper Productive Coal Measures."

The rocks of the Pennsylvanian series are, with few exceptions, extremely variable both in thickness and in lithologic character. However, this statement applies only to the individual members, the formations themselves differing but little in thickness from place to place. Usually there is a rather uniform thickening in one direction and not an irregular thickening in any direction. In the Foxburg-Clarion region, for example, the Allegheny formation ranges from 345 to 370 feet in thickness, there being a slight thickening to the northwest. The irregularity of the individual members is well stated by Richardson[31] as follows:

> Though a section in any one part of the quadrangle may have approximately the thickness and general character of a corresponding section in another part, it is likely to show many minor variations. This is very apparent in the field. On attempting, for instance, to trace a sandstone which at one locality is thick and prominent, it may be found that it soon becomes more shaly and less prominent and finally may lose its distinctive features and pass into a sandy shale, or even into a shale with no sand admixture. Farther along the same horizon the sandy phase may reappear, so that the horizon may again be marked by a prominent sandstone. The strata therefore frequently occur as lenses, and just as a sandstone merges into a shale, so limestone and shales pass by transition into one another from point to point. Any phase may be strongly developed locally and elsewhere may fade out or merge into something else. Such changes are characteristic of these upper Carboniferous rocks.

MONONGAHELA FORMATION

In the region south of the area considered in this report the Monongahela formation is of wide occurrence and of great economic importance. With the exception of a few small areas in the southern parts of Beaver, Armstrong, and Indiana counties the Monongahela forma-

[31] Richardson, G. B., U.S. Geol. Survey Geol. Atlas, Indiana folio (no. 102), p. 2, 1904.

tion has been completely eroded from the area here described. The greatest thickness remaining is along the Armstrong-Indiana County line, where about the lower 216 feet is present. The formation consists of shale, sandstone, limestone, and coal, with the Pittsburgh coal marking its base. The details of the different members are given in the county description for those counties in which they occur.

CONEMAUGH FORMATION

The greatest thickness of the Conemaugh formation in this area is more than 600 feet, but when traced eastward it increases to about 900 feet. It is predominantly a shaly formation, but the shale is in general more greenish than that of the underlying Allegheny formation. As many as four massive sandstones occur within the formation. These sandstone members are irregular both in thickness and in size of grain but are in many places similar and are therefore not easily distinguished from one another. Where massive beds are exposed, they have a marked effect on the topography. A number of thin beds of coal and limestone occur, but they are in general not persistent. In places some of the coal beds are of workable thickness. Probably the most persistent bed in the Conemaugh formation is the Ames limestone. It is a thin greenish rock that lies from 270 to 340 feet above the base of the formation. In places it is split into two beds.

The top of the Conemaugh formation is marked by the base of the Pittsburgh coal or its underclay, and because that coal is rather persistent the upper limit of the Conemaugh is as a rule easily determined. The base of the Conemaugh, which lies at the top of the Upper Freeport coal, is likewise readily determined in most places, because the Upper Freeport coal is rather persistent.

Because of the irregularity of the members making up the formation their detailed description is given in the separate county sections.

ALLEGHENY FORMATION

The Allegheny formation has a maximum thickness of about 360 feet. Although the formation as a whole has a rather uniform thickness the individual beds are in general so irregular, both in character and in thickness, that no one section can be regarded as typical. The formation contains most of the workable coal beds in the area here described. It contains about five coal-bearing beds in the western part of the State, but on the eastern edge of the coal basin as many as 12 coal beds are recognized. Richardson[32] has pointed out that caution is necessary in correlating these coal beds. He says:

> The generalized sections of this formation in the Allegheny Valley contain seven coals, which have been named Upper Freeport, Lower Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, Clarion, and Brookville. * * * These coals are all found somewhere, and the generalized sections are meant to show simply their relative positions. It is an error, however, to assume that all these coals must occur everywhere throughout the area in which the formation is found.
>
> Some workers in the field, not thoroughly realizing the facts as to the distribution of the coal, have assumed that these seven coals are actually continuous over wide areas and that wherever a coal is found in the Allegheny formation it must be correlated with one of the coals in the

[32] Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Indiana folio (no. 102), p. 4, 1904.

general section. But a careful consideration of the records of diamond drills that have pierced the entire formation or a study of complete natural exposures shows that fewer than seven beds of coal occur in the Allegheny formation, and that when neighboring sections are compared the coals in one cannot always be correlated with those of the other.

It is important to draw attention to these conditions, but at the same time it is by no means asserted that none of the coals of the Allegheny formation have a widespread and continuous distribution, for the Lower Kittanning in particular is remarkably persistent. When this variability is borne in mind, it becomes evident that it should not be lightly assumed that the presence of a bed of coal in one locality in the approximate stratigraphic position of a coal in another locality necessarily implies that the two coals are identical. Such identity appears to be tacitly assumed in the wide application of the same names for the coal beds of the Allegheny formation. But in the absence of proof of continuity it would seem to be preferable to have it understood that these names signify only approximate stratigraphic positions of the several coals, rather than identity.

The coals are generally separated by shale, and in many places underclays are present. Locally, sandstone beds also are conspicuous in the intervals between the coals.

With the exception of the Vanport the limestones in this formation are lenticular and over large areas do not make satisfactory horizon markers. The Vanport, however, in general is very persistent and where exposed or encountered in drilling is of great aid in determining the stratigraphic position.

The Upper Freeport coal marks the top of the Allegheny formation, and though not everywhere of workable thickness the coal is generally present where it has not been eroded away. The base of the formation is marked by the top of the Homewood sandstone. In some places the Brookville coal lies directly on the Homewood, but in others several feet of sandy shale intervenes. The Brookville coal is not everywhere present, nor is the Homewood sandstone everywhere massive, and therefore in some places the base of the Allegheny formation is not easily determined.

POTTSVILLE FORMATION

As shown below, the Pottsville lies on the eroded surface of the underlying formations and because of this unconformity is in contact with rocks that range in age from Mauch Chunk to Knapp.

In the region considered in this report only the upper part of the Pottsville formation is present. As much as 10,000 feet of rocks of lower and middle Pottsville age that are present in the southern Appalachians, are absent from the section in northwestern Pennsylvania. The Pottsville formation is divisible into five members, which, from bottom to top, are the Olean or Sharon conglomerate, Sharon shale, Connoquenessing sandstone, Mercer shale, and Homewood sandstone. The base of the formation is marked by the unconformity described on page 36. This unconformity brings the Burgoon sandstone (Mississippian) and the Connoquenessing sandstone together in many parts of the region, and as these two sandstones are lithologically in general almost indistinguishable from each other, it is difficult to determine accurately the lower limit of the Pottsville. The upper limit is likewise obscure in places, for the Homewood sandstone locally merges with shale, and the Brookville coal, at the base of the Allegheny formation, is not everywhere present.

On page 37 it is shown that conditions existed during Pottsville time that caused the overlap of the lower members of the formation. Thus, in most of the area where the Pottsville occurs it has a threefold character, the Connoquenessing sandstone being the basal member.

Owing to the uncertainty of determining the upper and lower limits of the Pottsville, its thickness is doubtful in many places. In parts of western Pennsylvania it attains a thickness of 275 feet. The areal distribution of the Pottsville formation is shown on plate 5.

The Homewood sandstone, the top member of the Pottsville formation, is known to the well driller by different names. In Venango and Clarion counties it is called the "Bluff sand," and along the Beaver River it is known as the "Gas sand," or in some localities as the "Forty-foot sand." The Homewood is one of the more persistent members of the Pennsylvanian series, though not everywhere is it prominent. It ranges from a coarse conglomerate with rounded quartz pebbles the size of a marble to a thin-bedded shaly sandstone and in some places appears to be completely replaced by shale with no admixture of sand. Where the sandstone is conglomeratic the pebbly portion may occur in any part of the member from top to bottom. It is white to gray, though in many places it is mottled with iron stains and in some places it is yellow or brown. This reddish-brown color is more characteristic of the upper part of the sandstone and appears to be the result of weathering. Exposed surfaces of the lower portions also indicate that the brown color is in part due to weathering. A water-well driller in Mercer County, who has put down a great number of wells into rock that is probably the Homewood sandstone, reports a change in color about every 20 feet, the upper 20 feet being yellow, the second gray, and the remainder white or in some localities yellowish. Not everywhere, however, is the brown color present, for in parts of the region the weathered rock is white, the absence of the brown color being due probably to the small amount of iron in the sandstone. This variation in color is found not only in this sandstone but in a general way also in all the other sandstones of the Pennsylvanian series. Cross-bedding is a rather common feature of the Homewood and is so prominent in places that the general appearance is that of a thin-bedded sandstone tilted at high angles. Generally the sand grains are not firmly cemented, the rock being rather soft and friable, particularly in the weathered portions. In places, however, the sandstone is firm and has been used to some extent for building stone. The member is as much as 70 feet thick in some localities, though the average for the region is probably only half as much. At the type locality, in Beaver County near the town of Homewood, it is 155 feet thick. This unusual thickness of the Homewood represents the combined interval of the Homewood of adjacent regions and either the Clarion sandstone above or the upper part of the Connoquenessing sandstone below. Where massive, the sandstone has a decided effect on the topography, forming cliffs in some localities and producing many extensive flats in the upland areas.

The Mercer shale member is predominantly shaly, though locally it has as many as three coal seams and two limestones. Fire clay is commonly associated with the coal. The member as a unit is rather persistent in occurrence but not in thickness, the individual coal and limestone beds being very irregular. In the northwestern part of the

Foxburg quadrangle the member is reported to be only a few inches thick, but in the New Castle quadrangle it reaches a thickness of 75 feet, although the average is about 20 feet. At least one of the coal beds is usually present, though commonly is not of workable thickness. The Mercer shale member is not resistant to erosion and for that reason has little effect on the relief. The top of the member is marked by the base of the Homewood sandstone, and the bottom by the top of the underlying Connoquenessing sandstone. The details of the Mercer shale member are described in the separate county sections.

Over much of the area in which the Pottsville formation occurs in northwestern Pennsylvania, the Connoquenessing sandstone is the basal member. It is one of the more persistent sandstones of the Pennsylvanian series in this region. The rock is generally coarse-grained and in places has the appearance of granulated sugar, both in texture and in whiteness. Like all the other Pennsylvanian sandstones, it is thin-bedded and shaly in some places but conglomeratic in others. It ranges in color from pure white to deep brown, though in most localities it is gray or yellowish. Like the Homewood, the Connoquenessing is rather soft in some localities, but in others the quartz grains are so firmly cemented together that the sandstone is very resistant to erosion. The member attains a thickness of more than 100 feet in many places, but 50 feet would probably be nearer the average for the area of its occurrence. Many extensive flats in the area of its outcrop owe their existence to the resistant Connoquenessing. In certain parts of the region this member is split into three divisions by a shaly carbonaceous bed that occurs between an upper and a lower sandstone. This carbonaceous bed has been called Quakertown. It is described under the counties in which it occurs.

The overlapping relations of the Sharon shale and the Olean conglomerate are described on page 37, and it is stated that over much of the area of the Pottsville formation the Connoquenessing sandstone is the basal member. However, in parts of the area as much as 70 feet of soft dark-bluish shale occurs below the Connoquenessing sandstone. Iron nodules are commonly present in this shale as well as irregular stringers of coal.

Near the base of the Sharon shale member is the Sharon coal, which was mined in the early days. It had a maximum thickness of 5 feet, but the areas of such thickness were small, and all the minable coal has been exhausted. In places the Connoquenessing sandstone rests on the Sharon coal, the intervening shale of the Sharon member being absent.

The Olean or Sharon conglomerate marks the base of the Pottsville formation in northwestern Pennsylvania. In Warren County the member is known as the Olean or Garland conglomerate. Because of the irregular surface on which it was laid down its thickness differs greatly in different places and is locally as much as 50 feet. It contains well-rounded quartz pebbles as much as 2½ inches in diameter. In places, however, it is not conglomeratic but is made up of moderately coarse sand grains, and in parts of Mercer County such rock has supplied a great amount of flagstone. When traced southeastward from the main areas of its outcrop, the conglomerate appears to thin out and is absent southeast of a line drawn roughly from Sheffield, in Warren County, to Sharon, in Mercer County[33]. Northwest of this

[33] Butts, Charles, U.S. Geol. Survey Geol. Atlas, Warren folio (no. 172), p. 6, 1910.

line the conglomerate is of widespread occurrence where it has not been removed by erosion.[34]

UNCONFORMITY BETWEEN THE MISSISSIPPIAN AND PENNSYLVANIAN SERIES

A clear understanding of the nature of the contact between the Mississippian and the Pennsylvanian rocks is essential to the interpretation of well records.

Detailed studies of the lowest member of the Pottsville formation within this area have shown that in different localities its base is in contact with different members and, in more widely separated areas, even with different formations. Thus, at one place in the Warren quadrangle the Pottsville lies on the lower member of the Knapp formation, whereas at a point 4½ miles to the south it rests on beds 200 feet or more above the lower Knapp.

Figure 8 is an ideal section showing the conditions existing at the end of Connoquenessing deposition between Scandia and Tiona, in the Warren quadrangle, a distance of more than 11 miles. The vertical scale and the dip of the pre-Pottsville formations are greatly exaggerated to bring out the relations more clearly. The section represents the conditions that would be seen in the vertical side wall of a deep trench cut into the earth's surface. The line a-a represents the land surface that was produced by the erosion of the underlying Mississip-

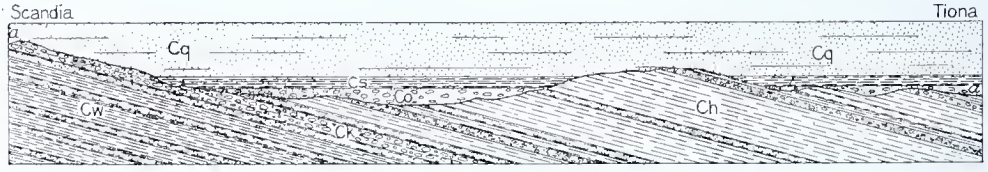


Figure 8.—Ideal section from Scandia to Tiona showing conditions at the close of Connoquenessing sedimentation

pian rocks. The evidence indicates that many hundreds if not thousands of feet of the upper Mississippian rocks were removed from the region by erosion before the first Pennsylvanian sediments were deposited. It is evident that an unconformity would still be present in this region even if the bedding planes of the Mississippian were parallel to those of the Pennsylvanian, as they are in many parts of western Pennsylvania.

Butts[35] describes the events that produced this unconformity as follows:

> Sedimentation was continuous over western Pennsylvania and eastern Ohio, with the deposition over that region of the Pocono-Waverly beds, probably in their full thickness of 1,000 feet or more, and, it may be, a considerable thickness of Mauch Chunk, though it is hardly probable that the latter formation reached the thickness of 2,200 feet, as in the anthracite field. At the close of Mauch Chunk time the region outlined above was broadly uplifted, the axis of uplift appearing to be somewhere in the neighborhood of a line extending from New Castle to the western corner of New York State. The uplift was also greater northward. During early and middle Pottsville time, while most of the Pottsville forma-

[34] White, I. C., Pennsylvania Second Geol. Survey Rept. Q⁴, p. 62, 1881.
[35] Butts, Charles, Pre-Pennsylvanian stratigraphy: Pennsylvania Top. and Geol. Survey Comm. Rept. for 1906-8, pp. 194-195, 1908.

tion with its included coal beds was being deposited in eastern Pennsylvania, the uplifted area was a land surface subject to erosion, with the result that the Mississippian beds, once probably present but now absent from western Pennsylvania, were removed. After this period of erosion a gradual subsidence began, and the land was transgressed by the waters in which the late Pottsville sediments were laid down. The submergence apparently proceeded from the northwest. Since the Olean conglomerate, the lowest member of the Pottsville in the region, lies to the north and west of a line roughly drawn from Wellsboro, in Tioga County, through Smethport, in Potter County, Sheffield and Tidioute, in Warren County, to Mercer and New Castle, in Mercer and Lawrence Counties, respectively, the most advanced shore line of the Olean waters apparently lay near the line just outlined. After the deposition of the coarse gravel making the Olean conglomerate, the land mass was entirely submerged and the Connoquenessing sandstone was deposited over the whole region, thus completing the cycle of uplift, erosion, submergence, and the resumption of deposition over the region affected by the unconformity.

After the erosion of the Mississippian rocks and the submergence of the area the first Pottsville sediments were laid down in the low places, and as the sea continued to rise the areal extent over which sediments were being deposited became greater and greater. In this way the younger sediments would overlap older ones so long as the sea continued to rise. Figure 8 shows the Sharon shale overlapping the Olean conglomerate and the Connoquenessing overlapping the Sharon shale.

Suppose a well driller who knows the rocks at Warren drills a well in the vicinity of Scandia. If the ideal conditions prevail, as shown in figure 8, he will pass through the Connoquenessing sandstone and enter the Knapp formation. If now he drills another well about midway between Scandia and Tiona he will pass through a greater thickness of the Connoquenessing, also the Sharon shale, the Olean conglomerate, and several feet of other rocks before entering the Knapp. He may then correlate the highest conglomerate of the first well with the highest conglomerate of the second well and consider the Sharon shale a local shaly phase of the Connoquenessing sandstone. Many other erroneous correlations might be made if the presence of the unconformity were not known. Other wells along the line of the section would show a different sequence of rocks below the Connoquenessing—all the result of the unconformity along the line a-a (fig. 8). In addition to this, of course, the problem is further complicated by the fact that erosion has cut into the surface rocks and produced a relief of more than 800 feet in places.

Southward from the Warren region the Pottsville rests on successively younger formations. In the Clarion region it lies on the eroded surface of the Burgoon sandstone, and still further south, in southern Indiana County, on the red shales of the Mauch Chunk formation. In the New Castle quadrangle it rests on the shales of the Cuyahoga formation, and in the Beaver quadrangle on the Burgoon sandstone, of the Pocono group.

MISSISSIPPIAN SERIES

MAUCH CHUNK FORMATION

As already noted, the Pottsville formation lies on the eroded surface of the Mauch Chunk formation in the southeastern part of Indiana

County, but in the region to the north and west the Mauch Chunk has been completely eroded away. According to Butts,[36]

> A line representing approximately the north and west edge of the Mauch Chunk would run west from a few miles south of Pittsburgh to the Ohio-Pennsylvania State line, and from the same locality northeast through Saltsburg and Indiana, probably crossing the southeastern corner of Jefferson County.

The Mauch Chunk crops out at only a few places in Indiana County along the Laurel Ridge and Chestnut Ridge anticlines. Its exposed thickness is probably not much over 50 feet, but some well borings penetrate more than 100 feet of rocks that probably represent the Mauch Chunk. The formation consists of red and green shales with some sandstone.

LOYALHANNA LIMESTONE

The Loyalhanna (Siliceous)[37] limestone crops out at three places in southeastern Indiana County. Near the mouth of Findley Run, a small tributary of the Conemaugh River in the southeast corner of Indiana County, the limestone is divided into two beds by a thin interval of red shale.[38] It crops out along Chestnut Ridge in the valley of the Conemaugh River[39] and with the Burgoon sandstone and Cuyahoga formation is well displayed in Packsaddle Gap through Chestnut Ridge. Platt[40] describes the occurrence of a limestone, which he calls the "Mountain" limestone in the valley of Black Lick Creek where it crosses Chestnut Ridge. Here the limestone forms "abrupt high cliffs along the water's edge". From his description of the limestone and its stratigraphic relations it appears to be the Loyalhanna. The limestone is in reality a calcareous sandstone about 40 to 50 feet thick and is made up of rounded quartz grains with admixtures of calcium carbonate. Cross-bedding is generally a striking feature, and because of this and other features Butts[41] believes it to be a wind-blown deposit. Like the Mauch Chunk formation, the Loyalhanna thins to the northwest and is believed to be absent over all of the area covered by this report except the southeastern part of Indiana County.

POCONO GROUP

Over much of northwestern Pennsylvania the Pottsville formation, where present, lies on the eroded surface of the Pocono group. Throughout extensive areas the basal rocks of the upper Pottsville lie upon similar rocks at the top of the Pocono, without any noticeable irregularity at the contact, and in such places the dividing line is difficult to determine. In many parts of the area the Burgoon sandstone is the top formation of the Pocono group. However, its upper portions were more or less eroded before the overlying sediments were

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[36] Butts, Charles, op. cit., p. 196.
[37] The name "Siliceons" has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey.
[38] Phalen, W. C., U.S. Geol. Survey Geol. Atlas, Johnstown folio (no. 174), p. 3, 1910.
[39] Butts, Charles, The Loyalhanna limestone of southwestern Pennsylvania, especially with regard to its age and correlation: Am. Jour. Sci., 5th ser., vol. 8, p. 249 1924.
[40] Platt, W. G., Pennsylvania Second Geol. Survey, Rept. H⁴, p. 59, 1878.
[41] Butts, Charles, op. cit., p. 251.

laid down, and it was, in fact, completely eroded away in some localities before the Pottsville was deposited.

In Crawford and adjoining counties the Shenango sandstone of I. C. White marks the top of the Pocono and is probably equivalent to part of the Burgoon sandstone. The names "Mountain sand" and "Big Injun sand" are in common usage by well drillers in many parts of western Pennsylvania for this sandstone, although the lower member of the Connoquenessing sandstone is also known as the "Mountain sand".[42]

The Pocono group in places has a threefold subdivision. From top to bottom it includes the Burgoon sandstone, Cuyahoga formation, and Berea sandstone. The Burgoon is one of the persistent sandstones of western Pennsylvania. It is as much as 450 feet thick in places, though it is generally much thinner. It is usually massive but in many places is shaly and contains lenses of shale. In many localities the sandstone is white, but in other places it is gray or buff.

The Cuyahoga formation consists mainly of shale, near the middle of which occur sandy beds. In the western part of the State it is divisible into three members, in descending order, the Meadville shale, the Sharpsville sandstone, and the Orangeville shale. These members appear to become more sandy eastward from their type locality, and in Ohio shale predominates. The Cuyahoga is more than 200 feet thick in places but commonly is thinner. Two rather persistent thin limestone beds occur in the formation, and these have been of great help in its recognition. The Berea sandstone is regarded as the base of the Pocono. It will be described in detail under the heading of the counties where it occurs.

UPPER DEVONIAN OR MISSISSIPPIAN ROCKS

Under this heading is included a group of rocks that may be either of Upper Devonian or Mississippian age. In the region considered in this report these rocks are subdivided into two formations,—the Knapp at the top and the Conewango at the base. This subdivision, however, does not apply in all of northwestern Pennsylvania, and for this reason detailed descriptions are given under the different counties.

DEVONIAN SYSTEM

UPPER DEVONIAN SERIES

The oldest rocks exposed in northwestern Pennsylvania are Upper Devonian. They crop out chiefly in the three northwestern counties,—Crawford, Erie, and Warren (plate 5). They consist in the main of shale and sandstone and are more than 1,000 feet thick in Erie County. Because of the change in character of the Upper Devonian rocks when traced from New York into Ohio a description of them is given under the headings of the counties where they occur.

STRUCTURE

Northwestern Pennsylvania lies in what is known as the Pittsburgh-Huntington structural basin, which extends southwestward from New

[42] DeWolf, F. W., New Castle quadrangle: Pennsylvania, Top. and Geol. Atlas no. 5, p. 200, Pennsylvania Geol. Survey, 1929.

York to Kentucky.[43] The rocks underlying this area dip in such a way as to form roughly a spoon-shaped basin—that is, the rocks dip from all directions toward the center of the basin, which lies somewhat to the southwest of the southwest corner of Pennsylvania. From the center of the basin outward successively older formations are exposed. The area covered by this report lies near the north end and chiefly on the northwest side of the axis of the basin. In most of the area the regional dip is about 15 to 20 feet to the mile, which is so slight that the rocks appear to be essentially horizontal. However, in the southeastern part of the area the rocks have been folded into anticlines (upfolds) and synclines (downfolds), which trend roughly northeastward. In the anticlines the rocks dip away in both directions from the axes, and in the synclines they dip from both sides in toward the axes. From northwest to southeast the dips along successive folds become steeper until in the southeast corner of Indiana County, along the Laurel Ridge anticline, the dip is 1,000 feet to the mile. Although the dominant trend of both major and minor folds is northeast, there are numerous cross folds, the axes of which form angles with the trend of the major folds. In the areas where the rocks have a slight, more or less regular dip there may be slight reversals of dip which produce broad, low anticlines or domes. In these areas, however, the dips are so gentle that only after careful instrumental determinations of the lay of the rocks do these minor folds become apparent.

The rocks of this area were laid down essentially in a horizontal position. After their deposition they were subjected to forces that caused them to assume their present attitude. These forces were of two types—those that caused uplift or depression and those that acted horizontally, compressing the rocks into folds. These compressive forces probably came from the southeast and produced the closely folded mountains of central Pennsylvania. The process is illustrated on a miniature scale by pushing with the hands on one edge of a tablecloth, thus causing it to wrinkle into parallel ridges.

It is apparent, in view of the unconformity described on page 36, that the rocks below this erosion surface might have been deformed before the overlying sediments were laid down, in which case the structure of the older rocks might not be the same as that of the younger ones. Although this is true to some extent in northwestern Pennsylvania, there is a general agreement between the structure of the surface rocks and that of the deeper ones. The details of the structural axes are described under the individual counties.

GROUND WATER

SOURCE

It is a common belief of many people in northwestern Pennsylvania that the water in wells and that issuing from springs moves through the ground by means of underground channels—or "veins" as they are called—which if traced to their source would be found to originate in some lake or river. Lake Erie is supposed by some people to be the source of much of the ground water in the northern part of the area. As Lake Erie is only 573 feet above sea level, which is considerably lower than the level to which the water rises in wells in the area to

[43] Richardson, G. B., Structure contour maps of the Pittsburgh-Huntington Basin; Geol. Soc. America Bull., vol. 39, pp. 543-553, 1928.

the south, the possibility of such a source is at once eliminated. Likewise the idea prevails in Mercer County that Sandy Lake supplies the ground water in that vicinity, although the lake lies about 300 feet lower than the surrounding country. In Warren County it is thought that much of the ground water comes from Chautauqua Lake, N. Y., which is 200 to 900 feet lower than most of Warren County.

It has long been known that by far the greater part of the water in the outer portions of the earth comes from rain and snow. Some people think that rainfall and snowfall are too small in quantity to supply the large quantities of water stored in the ground. It should be borne in mind, however, that a layer of water 1 inch deep over 1 square mile amounts to more than 17,000,000 gallons and that in northwestern Pennsylvania the average annual precipitation is more than 40 inches. Of the water that falls as rain or snow in this region about half flows directly into the streams, and most of the remainder

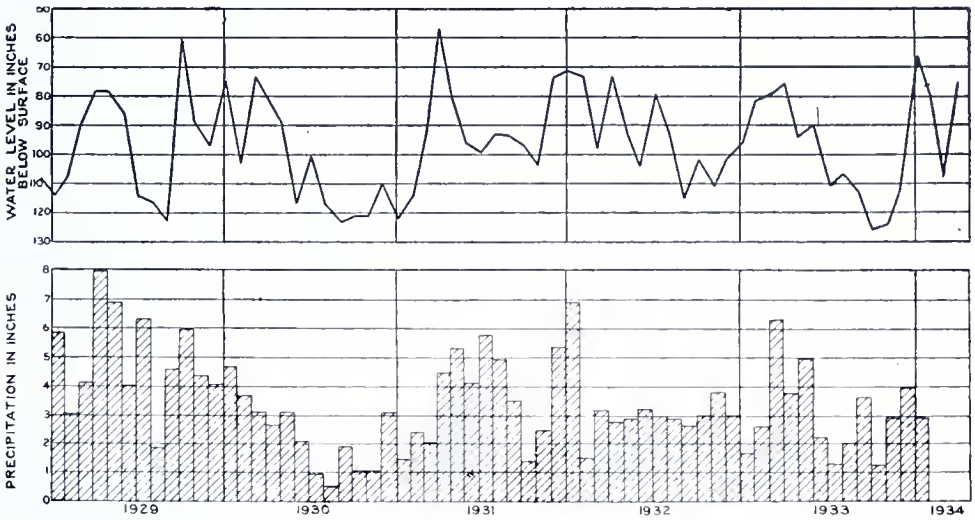


Figure 9.—Hydrograph of dug well in Sligo, Clarion County, and precipitation at Parkers Landing, Pa.

sinks into the ground, only a small part being evaporated directly. Some of the water that seeps into the ground is stored in the soil as soil moisture and is eventually returned to the atmosphere, either by evaporation from the soil or by the absorption and transpiration of plants, and some of it passes on through the soil and is added to the main body of ground water.

Figure 9 shows the fluctuations of the water level in a dug well (well 459) in Sligo, Clarion County. Measurements to the water level were made near the first of each month by G. W. Texter. To some extent distribution of rainfall throughout the month accounts for some of the high points on the curve. The measurements made on October 2, 1929, and April 1, 1931, were preceded by rainy days, whereas some of the low points on the curve were preceded by a number of rainless days. In general, however, the water level is highest in the first half of the year and lowest in the second half. This is not the result of the distribution of precipitation, because June and July are the wettest months. Each year the water level begins to drop in the spring, when plant growth begins and evapora-

tion becomes greater. Much of the precipitation that falls in the summer does not reach the water table but is used by plants or evaporated. The greatest annual fluctuation in the Sligo well is about 5½ feet.

The graphs in plate 6 show fluctuations of water level in seven shallow observation wells in northwestern Pennsylvania. The measurements were made weekly with steel tapes by local observers. These measurements were a part of a State-wide project for determining systematically the fluctuations of ground-water levels. [44]

The effect of rainfall on the yield of a spring is shown by measurements of a small spring just east of the Rimersburg borough line. On October 15, 1928, the writer by measurement with a gallon container and a stop watch found the yield of this spring to be 1.8 gallons a minute. According to the records of the United States Weather Bureau station at Parkers Landing, about 10 miles northwest of Rimersburg, the total rainfall for the first 15 days of October was 0.41 inch. October 16, 17, and 18 were rainy days for most of Clarion County, the records at Parkers Landing showing a total of 2.14 inches for the three-day period. On October 19 the yield of the spring was again measured and found to be 4.1 gallons a minute. Thus, within a period of four days the yield of this spring more than doubled. This condition is probably typical of many of the smaller springs in northwestern Pennsylvania.

About 78 per cent of the yearly precipitation occurs during the 9 months of spring, summer, and autumn, when the ground is not frozen, and much of the snow that falls when the ground is frozen in the winter seeps into the soil during subsequent periods of thaw.

OCCURRENCE [45]

General Conditions.—The rocks [46] of the outer portion of the earth are not entirely solid but contain openings or voids that are filled either with liquid or with gas. The liquid may be water, oil, or other liquid material, and the gas may be air, natural gas, or other gaseous material. These voids range in size from microscopic openings to large caverns, such as are found in limestone regions. In northwestern Pennsylvania the openings in which ground water occurs are of two kinds—the pore spaces between the grains of the rock and the joints of "crevices" that have resulted from fracturing of the rocks.

The amount of water that can be stored in a given rock depends on its porosity—that is, the percentage of pore space to the total volume of the rock. Many unfractured rocks have porosities of more than 30 percent and some even more than 60 percent. [47] The size of the grains making up the rock does not of itself determine the porosity. A fine-grained rock that contains numerous small openings, such as silt or clay, may be just as porous as coarse sand or gravel. However, not all of the water filling the pore space of a saturated rock becomes available to wells drilled into that rock. Suppose a block of

[44] Lohman, S. W., Replenishment of ground water recorded by observation wells in Pennsylvania: Dept. Interior Press Mem. 62307, April 27, 1932.

[45] For a more comprehensive treatment of this subject see Meinzer, O. E., The occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, 1923.

[46] The term "rock" is applied to the unconsolidated surface deposits as well as to the hard bedrock.

[47] Stearns, N. D., Laboratory tests on physical properties of water-bearing materials: U. S. Geol. Survey Water-Supply Paper 596, p. 134, 1927.

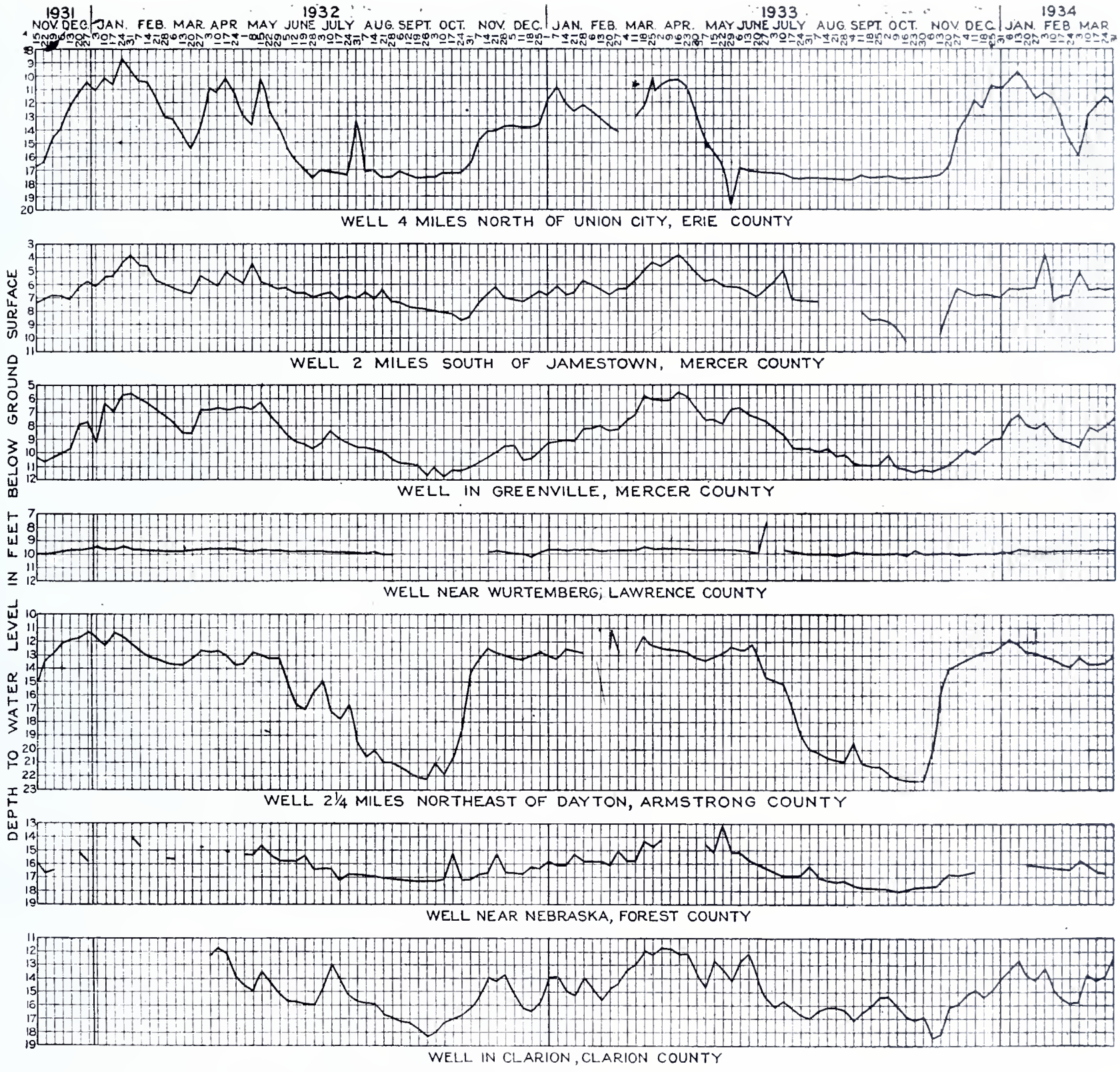


Plate 6.—Graphs Showing Fluctuations of Water Fuel in Seven Shallow Wells in Northwestern Pennsylvania

rock is immersed in water until all the voids are filled. Upon lifting the block out of the water part of the liquid in the pores will drain out on account of the force of gravity. Some of the water, however, will be held in the pores by the molecular attraction of the grains of the rock. As the effect of molecular attraction is in proportion to the aggregate rock surface that comes into contact with the water, and as the aggregate surface varies immensely with the size of grain, it is obvious that, for a given porosity, a coarse-grained rock will yield more water than a fine-grained rock. Porosity alone, therefore, does not determine the water-bearing properties of a rock.

Suppose a gravel to be made up of spherical pebbles of uniform size arranged in the most compact fashion. If to a cubic yard of this gravel fine sand is added, the porosity of the cubic yard of material will be reduced, because the sand will occupy the voids between the spherical pebbles. If, moreover, a boulder of solid nonporous rock is added to the sand and gravel mixture and enough of the mixture is removed to leave only a cubic yard of material, the porosity of the cubic yard will obviously be still further reduced, because the boulder will occupy space that originally contained pores between the sand grains. It is therefore apparent that although well-assorted coarse-grained and well-assorted fine-grained deposits may have the same porosity, a mixture of the two is likely to be less porous than either.

The permeability of a rock is its capacity for transmitting water under pressure. A fine sand may have a high porosity, but because of the small size of its pores it may offer so much resistance to percolation of the water that its permeability will be low, whereas a coarse sand with the same porosity may be very permeable. A bed of clay may have as high a porosity as deposits of sand, but because of the extremely small size of its pores it may be entirely impermeable.

From what has already been said it is evident that a well may be sunk into rock which, though saturated with water, will yield essentially none because of the small size of the rock pores. Such a well would be called a dry hole by the driller, and he would likely be of the opinion that the rock contained no water.

The openings in rocks that have so far been considered are known as "original openings," because they are essentially the spaces that remain between the adjacent grains of sedimentary deposits. Secondary openings, on the other hand, are those that were formed after the sediments were deposited. Joints or "crevices" are examples of this type, and in northwestern Pennsylvania they are of considerable importance in yielding ground water. Such openings in the rocks have been produced by stresses that accumulate until the rocks are fractured. The opposite walls of a joint plane may either be in contact with each other or may stand apart and form an open fissure. Joints may be long or short. They commonly occur in sets, in which the individual joints are more or less parallel, and in many places two or more sets intersect each other. They are generally most numerous near the surface, becoming fewer and smaller with depth. Openings of this kind not only allow free movement of water but permit the storage of large quantities. The occurrence of ground water along joints is probably the source of the erroneous conception that all ground water is found in "veins." Plate 7-A shows an open joint about 6 inches wide in a sandstone of the Conewango formation. If

a well encountered such an opening below the water table it would yield considerable water. In the left center of the illustration water can be seen seeping from openings along bedding planes.

The upper surface of the zone of saturation is known as the water table. In northwestern Pennsylvania the water table is generally at a slightly higher altitude beneath the uplands than beneath the adjacent valleys, even though it lies farthest below the surface beneath the uplands. This general slope of the water table toward the streams shows that the movement of the ground water is generally toward the

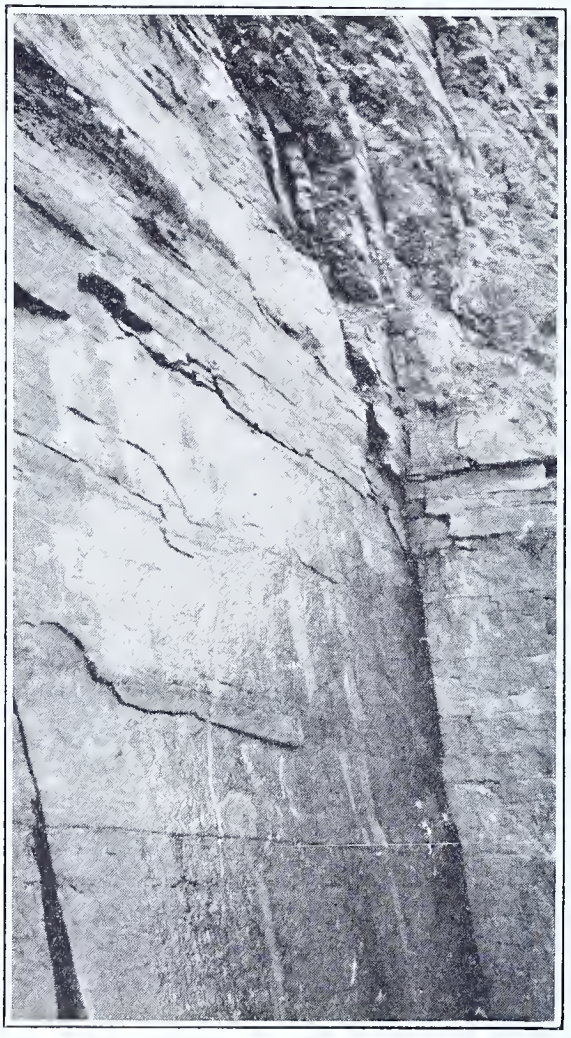


Plate 7A.—An open joint in a sandstone of the Conewango Formation near West Hickory, Forest County, Pa.

streams. Contrary to the common conception, therefore, the streams in this area are commonly gaining water from the ground and not losing it to the ground. There are, of course, minor exceptions to this rule, for during short intervals immediately after heavy rains the streams may rise above the adjacent ground-water levels. During the seasons when plant growth is at a minimum the water table is built up by percolation of the water derived from rain and snow and stands considerably above the adjacent stream levels. However, during the

growing season the water table declines because water is constantly draining out of the ground and but little is being added to the water table by precipitation.

Wells drilled in many parts of northwestern Pennsylvania encounter water which is under artesian pressure and which therefore rises in the wells and may overflow at the surface. In the southeastern part of the area covered by this report artesian conditions occur along the synclines, where the water moves down the dip of the beds. In other parts of the area, where the rocks are essentially horizontal, artesian conditions are also present, both in the glacial outwash and in the bedrock formations, but the artesian pressures are commonly not sufficient to produce flowing wells.

Glacial drift—Till, which is unstratified material laid down directly by the glacial ice, is composed of poorly assorted material and therefore generally has only low porosity. The spaces between the coarser material are more or less filled with silt and clay, and, as already pointed out, this arrangement of material results in low porosity. In northwestern Pennsylvania there appears to be but little water derived from till. The till, however, is rather stony, and it may be that some of the wells reported by drillers to end in gravel are in reality yielding water from stony till.

Glacial outwash was subjected to the sorting action of water, and this resulted in the separation of the fine and coarser material. The grains of rock deposited at any one place at a given time were more or less of uniform size, and thus deposits of high porosity were laid down. According to Meinzer[48]:

> Gravel is the best kind of formation to yield water. In the United States it supplies most of the strong wells and furnishes more water to wells than all other materials taken together. A coarse clean gravel has a high porosity, high permeability, and high specific yield (the ratio of the volume of water produced to the volume of the rock yielding the water). It absorbs water readily, stores it in large quantities, and yields it to wells freely.

The glacial outwash gravel is by far the largest producer of water in northwestern Pennsylvania. Most of the large industrial and municipal users of ground water obtain their supply from outwash gravel, both in the glaciated area and south of the glacial boundary. Plate 4 shows the distribution of outwash material in the area here described.

Sandstone—Next to glacial outwash, sandstone is the most valuable water-bearing formation in northwestern Pennsylvania. In many parts of the glaciated area, as well as outside the glacial boundary, water from sandstone supplies the industrial, municipal, and domestic needs.

There are all gradations between a rock made up entirely of clay particles and one that consists entirely of sand grains or pebbles—that is, a rock may consist of large or small particles of uniform size or may be composed of a mixture of fine and coarse material in varying proportions. All sandstones were originally composed of loose grains of rock, which later were more or less cemented together by the deposition from solution of calcium carbonate, silica, or other mineral matter in the pore spaces. There are all gradations

[48] Meinzer, O. E., op. cit., p. 117.

between a loose, unconsolidated sand and a very hard, compact sandstone. The permeability of a sand decreases as the pore spaces become filled with cementing material. However, a certain amount of cementation is advantageous because it keeps the sand grains from moving into the well—a condition that causes a great deal of trouble in many wells. Other things being equal, joints are more likely to develop in highly consolidated rocks than in relatively unconsolidated materials. Cementation may therefore indirectly produce better water-bearing conditions.

Water may occur in sandstone in the pore spaces of the rock, along the joints, or in both types of openings. Where the rock is compact and tightly cemented, water in appreciable quantities will be obtained only where fractures are encountered. The size of grain, degree of assortment, degree of cementation, and amount of jointing are the factors that determine the water-bearing properties of a sandstone.

In northwestern Pennsylvania more than twenty distinct sandstone beds have been recognized. They are, with few exceptions, very irregular in character. Most of them are prominent only locally, but some of them are found over large areas. Even these beds of widespread occurrence are extremely variable in those characters that determine their water-bearing properties. It is therefore impossible to describe the water-bearing properties of any one sandstone. If a sandstone lies below the water table and is permeable it may yield moderate supplies of water.

Shale—Many of the domestic supplies of the area are obtained from shale. Although much of the shale has considerable porosity, the pores are so small that most of the water is retained in the rock and does not become available to wells. In many places, however, the shale is broken by joints along which water moves. Bedding planes also permit the storage and movement of water. Openings of this kind if encountered below the water table will supply small quantities of water, usually enough for domestic use. It seems probable that many of the wells reported by drillers as ending in shale or "slate", actually end in sandy shale. The commonly used terms "slate" and "shells" probably refer to a thin-bedded sandstone, such as is shown in plate 7-B.

Coal—In parts of northwestern Pennsylvania beds of coal yield considerable quantities of water. In these localities the coal is more or less broken into blocks, and the fractures allow considerable movement and storage of water. Numerous springs issue from the outcrops of coal beds. Impermeable clays or shales commonly underlie the coals and act as confining beds that keep the water in the coal. In many places the waters in the coal are highly mineralized, and in such localities the drillers usually case through the coal and drill for deeper water. In some localities the water yielded by coal beds is not high in iron unless the coal has been worked near by. The pyrite in the coal is the chief source of the iron, and unless air has come into contact with the pyrite, oxidation has not taken place to any great extent and therefore only small quantities of iron are present in soluble form.

RECOVERY

Ground water is recovered for use chiefly by means of wells. However, in many parts of northwestern Pennsylvania springs are utilized

for both domestic and municipal supplies, although the quantity of water thus obtained is usually small. The municipal supply at Monaca is obtained from an infiltration crib. (See p. 85.) Where the water table lies near the surface, dug wells are commonly used, but they are more likely to become contaminated than deeper drilled wells. The area through which water moves into a well is generally greater in a dug well than in a drilled well. Therefore, when small quantities of water are required in a region of poor water-bearing material and shallow water table, a dug well may be more desirable than a drilled well. In most of the area ground water is recovered for domestic, industrial, and municipal supplies by means of drilled wells. Wells



Plate 7B.—Thin-bedded sandstone exposed in south bank of Allegheny River, about 1 mile upstream from Oil City, Venango County, Pa.

drilled through sandstone are usually not cased except near the surface, unless it is desired to shut off undesirable water. The water therefore enters the well along the entire wall of the hole where the rock is water-bearing. However, wells drilled in unconsolidated sand and gravel are cased to the bottom to prevent caving. Water moves into such wells only through the open end of the casing. The area of intake opening of some wells is increased by drilling holes in the lowest few feet of the casing. Unless a test well has previously been drilled such holes may not be of the size best suited to the material with which they will be in contact, because the size of the water-bearing material in which the well will end is not known at the time the pipe is perforated. In only a few wells have definite attempts been made to develop the full capacity of the water-bearing formation during the construction; in all other wells the development is confined to the small amount that takes place in cleaning by the initial pumping or the natural flow.

When water is withdrawn from a well either by natural flow or by pumping there is a difference in head between the water inside the

well and the water in the ground outside the well. The pressure surface in the vicinity of a well discharging water has the form of an inverted cone, the apex of which is at the center of the well and the slope of which becomes less the greater the distance from the well. This is known as the "cone of depression" and is necessarily present around any well that is discharging water. Where there is a water table—that is, where the ground water is not under artesian pressure—the water-bearing material lying within the cone of depression has been unwatered, and the distance from the static water level to the apex of the cone of depression is the drawdown of the well for that particular pumping rate. Under artesian conditions the cone of depression is an imaginary cone in the pressure-indicating surface, and the apex of the cone in a well that is flowing is the point of discharge of the well, the drawdown being equal to the distance from the point of discharge to the static water level. Under both water-table and artesian conditions the slope of the cone of depression depends on two factors—the permeability of the water-bearing material and the rate at which water is being withdrawn from the well.

Much larger quantities of water could be withdrawn from many wells in northwestern Pennsylvania if more modern and efficient well construction had been used. In general, wells of small diameter are inefficient where large quantities of water are necessary. The velocity of water moving toward a well increases as the well is approached, because the water is moving through a continuously decreasing cross sectional area. The maximum velocity of water is therefore at the periphery of the well casing, which is the point where friction losses limit the amount of water entering the well casing. It is therefore obvious that for a given quantity of water supplied by a well the friction losses are less at the periphery of a well of large diameter than at the periphery of one of small diameter.

Other things being equal, the greater the area of intake opening of a well the greater the amount of water that can be withdrawn from it with a given drawdown. It is therefore desirable to increase the area of intake opening of a well in such a manner that the velocity of water entering the well will be held to a minimum. Furthermore, because the intake area of most wells in northwestern Pennsylvania is limited to the area of the open end of the casing, many wells continuously yield large quantities of fine sand or muddy water and often fill up with sand.

The intake opening of a well is sometimes increased by perforating the lower end of the casing with holes or slots, but unless the open end of the casing is closed, sand or fine material is likely to move up through the open end and plug the part of the casing that is perforated. In modern well construction a specially manufactured screen or strainer is placed below the end of the well casing, in contact with the water-bearing material. The end of the screen is closed and all the water entering the well passes through the screen. The size of the screen opening is determined after making a mechanical analysis of the water-bearing material that will be in contact with the screen. In this manner maximum intake opening and minimum difficulty from sand trouble are obtained. Well screens are made in which as much as 20 per cent of the screen area is intake opening. The following table shows the approximate area of intake openings of open-end casings, perforated casings, and well screens:

Approximate area of intake openings of open-end casings, perforated casings, and well screens.

Diameter of casing (inches)	Intake area of open-end casing (square inches)	Intake area of 5-foot length of perforated casing and well screen, closed end (square inches)		
		Casing perforated with ¼-inch holes on 3-inch centers	Well screen	
			Intake area 10 per cent of screen area	Intake area 20 per cent of screen area
12	113	14	226	452
6	28	7	113	226
4	13	5	76	151
2	3	2	38	75

In view of the benefits that are to be derived from an adequate area of intake opening in a well, the advantage of well screens over perforated pipe or open-end casing is apparent from the above table.

A mixture of coarse and fine material will yield less water than the coarse material alone. Glacial outwash gravel usually has more or less fine material mixed with the coarse pebbles. It is obvious that if by some method the finer grains could be removed a better water-bearing formation would be produced.

Properly constructed wells are subjected to a period of development after the screen has been placed. Different methods of development are used such as pumping the well at a high rate, preferably by the air-lift method, "surging" by means of plungers or by changing the rate of pumping, or releasing compressed air in the well in such fashion that water is forced through the screen into the water-bearing material. All methods of development serve the purpose of removing the fine material from the water-bearing formation in the vicinity of the well tube, where the water velocity is highest, for at this place the maximum permeability of water-bearing materials is desirable. The removal of the fine material increases the permeability for a short distance away from the well. Furthermore, because the velocity of the water determines the size of particles that can be moved, the well should be developed to yield water at a rate in excess of that contemplated when the well is later put into operation. This removes all or most of the particles of a size that could be moved when the well is pumped at the higher rate, so that later, when the well is put into operation at the normal rate, very little difficulty from sand should be experienced. The openings in well screens are usually made large enough to allow from 50 to 80 percent of the water-bearing material to be drawn into the well and removed during the period of development. The period of development is usually at least 24 hours and for some wells several days. If the size of screen opening has been designed to permit a large percentage of the water-bearing material to be removed, the period of development should be somewhat longer than otherwise.

QUALITY OF WATER

The mineral constituents of natural waters here considered include all that are found in normal waters in quantities sufficient to have

any practical effect on the value of the waters for ordinary uses. The following statements concerning the mineral constituents of natural waters have been prepared by W. D. Collins, chemist in charge of the quality of water division of the U. S. Geological Survey.

Silica (SiO_2) is dissolved from practically all rocks. A few natural waters contain as little as 3 parts per million of silica, and some contain more than 50 parts, but most of them contain from 10 to 30 parts per million. Silica does not affect the usefulness of a water except as it contributes to the formation of boiler scale.

Iron (Fe) is dissolved from many rock materials and may be dissolved from water pipes in quantities so large as to be objectionable. On exposure to the air, water that contains more than 1 part per million of iron soon becomes turbid with the insoluble compound produced by oxidation; surface waters therefore rarely contain as much as 1 part per million of dissolved iron. Many ground waters contain 2 or 3 parts per million, and some even 10 parts or more. Excessive iron in water causes stains on white porcelain or enameled ware and fixtures and on clothing or other fabrics washed in the water.

Calcium (Ca) is dissolved from practically all rocks but particularly from limestone, dolomite, and gypsum. Calcium and magnesium make water hard and are the active agents in forming boiler scale. Magnesium (Mg) is dissolved from many rocks but particularly from dolomite. Its effects are largely similar to those of calcium, but waters that contain much magnesium and chloride are likely to be corrosive, especially in steam boilers.

Sodium and potassium (Na+K) are dissolved from practically all rocks, but they make up only a small part of the dissolved mineral matter in most waters in humid regions. The waters of many deep wells are strong solutions of common salt (sodium chloride) and contain smaller quantities of other soluble salts. Sodium and potassium are generally not separated in analysis. Moderate quantities of these constituents have little effects, but waters that carry more than 50 parts per million of the two may require careful operation of steam boilers to prevent foaming. Waters that contain large quantities of sodium salts injure crops, and some waters contain so much sodium that they are unfit for nearly all uses.

Carbonate and bicarbonate (CO_3 and HCO_3) occur in waters largely through the action of carbon dioxide, which enables the water to dissolve carbonates of calcium and magnesium. Carbonate is not present in appreciable quantities in many natural waters. The bicarbonate in waters that come from insoluble rocks may amount to less than 10 parts per million; many waters from limestone contain from 200 to 400 parts per million; and certain waters that contain sodium bicarbonate may carry 1,000 or more parts per million of bicarbonate. The bicarbonate as such has comparatively little effect, although a large quantity may make water unsatisfactory for drinking and other domestic uses.

Sulphate (SO_4) is dissolved in large quantities from gypsum and from deposits of sodium sulphate. It is also formed by the oxidation of sulphides of iron and is therefore present in considerable quantities in waters from mines and from many beds of shale. Sulphate in waters that contain much calcium and magnesium causes the formation of hard scale in steam boilers and may increase the cost of softening the water.

Chloride (Cl) is dissolved in small quantities from rock materials in most parts of the country. The chloride in waters has little effect on their use unless it is present in excessive quantities, as in brines.

Nitrate (NO_3) in water is considered a final oxidation product of nitrogenous organic material. The quantities usually present have no effect on the value of water for ordinary use.

Hardness is usually expressed as the quantity of calcium carbonate ($CaCO_3$) equivalent to the calcium and magnesium present. Water that has less than 50 parts per million of "hardness", as thus determined, is usually rated as soft, and its treatment for removal of hardness is rarely justified. Hardness between 50 and 150 parts per million does not seriously interfere with the use of water for most purposes, but it does slightly increase the consumption of soap, and its removal by softening processes will be profitable for laundries or other industries that use large quantities of soap. Hardness beyond 150 parts

per million is noticed by anyone, and in many places where natural waters have hardness of 200 to 300 parts per million cisterns are used for storing rain water for use in laundry work.

As would be expected from the fact that most of the members of the various rock formations in northwestern Pennsylvania are irregular in composition, the amounts of dissolved mineral matter in waters from the different members vary widely and are not characteristic for any one member. Even when considered on a lithologic basis, the waters from sandstone, shale, and glacial drift are not radically different in the amounts of the various mineral constituents, each of the groups showing both high and low values for all the mineral constituents. There are, however, a few generalizations that may be made, though too much reliance should not be placed on averages. It should also be remembered that an average based on figures that range from high to low is of little value in attempting to predict the approximate quantity of any one mineral constituent. In many wells water enters at a number of different depths and from different types of rock. The well water is therefore a mixture and is not characteristic of any one rock. The following table shows the maximum, average, and minimum amounts of dissolved mineral matter in waters from glacial drift, sandstone, and shale:

Maximum, average, and minimum amounts of dissolved mineral matter in waters from glacial drift, sandstone, and shale in northwestern Pennsylvania.

[Parts per million—excessively large or small quantities excluded in determining averages.]

	Water from glacial drift (36 analyses)			Water from sandstone (34 analyses)			Water from shale (10 analyses)		
	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum
Total dissolved solids	881	280	124	3,186	259	23	3,826	303	136
Silica (SiO_2)	30	15	6.6	22	12	5.8	16	12	6
Iron (Fe)	4.03	0.65	.01	42.0	2.9	.01	10.98	.28	.02
Calcium (Ca)	190	55	22	188	30	2	40	26	6
Magnesium (Mg)	26	11	6.1	37	8	1.8	14	9	5.9
Sodium and potassium (Na + K)	111	27	2.2	963	56	1	1,438	81	6
Bicarbonate radicle (HCO_3)	292	154	88	408	165	6	862	234	10
Sulphate radicle (SO_4)	331	62	5.1	225	30	1.5	195	21	2
Chloride radicle (Cl)	144	27	1.2	1,761	39	1	1,868	31	2.7
Nitrate radicle (NO_3)	50	9	.05	12	0.81	0	25	1.3	0
Total hardness	582	182	81	622	106	17	152	96	34

There seems to be but little difference in total dissolved solids for the three groups. The maximum and minimum amounts of iron in the three groups are about of the same order, but the waters from sandstone in general contain much more iron than those from the other two groups. Calcium and magnesium show no outstanding differences for the three groups, though the waters from the glacial drift probably contain the greatest quantities on the average. Exclusive of waters that are clearly contaminated with salt-water brines, the waters from shale contain the greatest amount of sodium and potassium and those from glacial drift the least. The waters from shale are higher in

bicarbonate than those from the other two groups. The waters from glacial drift average more than twice as much sulphate as those from shale and sandstone. The depth at which salt water is encountered differs in different localities. Its occurrence is probably related to depth and not to the type of sediment that yields the water. In general, the amount of sodium chloride is less in water from glacial drift than in those from shale or sandstone. The water from glacial drift is on the average considerably harder than water from the other two groups. Many of the waters from glacial drift have a hardness of more than 200 parts per million, which is considerably above that of most of the waters from shale or sandstone.

Over the greater part of northwestern Pennsylvania the most objectionable mineral constituent in ground water is iron. Treatment for removal of other undesirable constituents is carried on in parts of the region, but the need for such removal is not so general as that for the removal of iron. The treatment of water for public and industrial supplies is described in a manual issued by the American Water Works Association. [49]

It has been stated that waters containing more than about 1 part per million of iron becomes turbid when exposed to air. The table of analyses shows that many of the waters in use in this part of the State contain much more than 1 part per million of iron. This is particularly true of the waters derived from sandstone. The chemistry of iron dissolved in natural waters is somewhat complicated and not fully understood. [50] When well water is brought to the surface some of the dissolved gases pass off, and this decreases the solubility of the iron in solution and tends to bring about precipitation. When the water reaches the surface it comes into contact with the oxygen of the atmosphere, and this oxidizes the iron and causes its precipitation. In the summer the temperature of the water is raised after it reaches the surface, and this also favors precipitation. In collecting samples of water in the field the results of these processes were, for some samples, very striking. A bottle of clear water collected from a well would become quite cloudy in less than half an hour. The samples of water were analyzed in the Geological Survey laboratory about a month, on the average, after the time of collection. During this period the waters were exposed to the atmosphere only the few moments while passing from the well into the bottle. In 38 analyses the precipitated iron and the iron in solution were determined separately, and in all but one of these analyses no more than 0.08 part per million of iron remained in solution, though the total iron in solution at the time of collection was in some samples greater than 10 parts per million. Some of the samples were not entirely clear when collected, there being small flakes of iron rust in the water, which presumably came from the well casing. This rust was of course included in the determination of the precipitated iron, and in such anaylses the quantity of iron reported is greater than the actual amount of iron originally in solution.

It is therefore evident that most of the iron can be precipitated by aeration. One of the common methods of aeration is by means of a series of nozzles which spray the water into the air and thus allow the

[49] Water works practice, 814 pp. see also p. 4. Baltimore, Williams & Wilkins Co., 1926.

[50] Weston, R. S., The physical chemistry of deferrization: Am. Water Works Assoc. Jour., vol. 9, pp. 491-495, 1922.

air to come into contact with each drop of water. Another method is to cause the water to flow over a series of steps. At each of the little waterfalls the air comes into contact with both sides of the thin layer of water. It remains, then, to remove the precipitated iron from the water. This can be done either completely or partly by various methods. Probably the best method is filtration either with or without coagulation. It is desirable to delay the filtration for a time after aeration, so that all or most of the iron is allowed to precipitate and also so that some of the precipitated particles may settle. The precipitated iron in some waters may consist of particles so large that they will settle out in a short time. However, in some samples the precipitate is so fine that very little settling takes place. With some waters the iron may be greatly reduced without filtration if after aeration it is allowed to stand in a tank, from the surface of which it is later drawn off. This method is being used by some of the smaller towns in northwestern Pennsylvania that have not been able to stand the expense of a filter. Two reservoirs, or one with a partition, are used. The first receives the water after aeration, and after a period of settling the water is drawn off into the second reservoir, from which it is distributed to the town. With some waters the iron can be materially reduced by causing the water from the well output to fall on a rack or tower that is filled with coke, after which the water is allowed to stand so that the precipitated iron may settle. The removal of iron from ground waters is described in detail by McNamee.[51]

Many industries use large quantities of water for cooling. For such uses the chemical character of the water is of little importance, but it is desirable to have water which not only has a relatively low temperature but which also has an approximately constant temperature the year round. Hence ground water is better adapted for cooling than surface water. The temperature of ground water that is not too near the surface tends to be approximately that of the mean annual temperature of the atmospere in that locality, or slightly higher. However, local conditions may materially alter this general relation. The mean annual temperature at numerous stations in northwestern Pennsylvania is given on page 11.

In many parts of northwestern Pennsylvania deep wells encounter water that is high in sodium chloride (NaCl). Salt water is also encountered in shallow wells, although in some places the salt water is brought up from greater depths by old oil or gas wells that leak at the shallower horizons. (See analyses 9, 325, 477, and 502.) Salt water is not likely to be encountered at depths above drainage level where there is adequate circulation of fresh water. Many of the rocks of northwestern Pennsylvania were laid down beneath sea water, some of which was entrapped in the sediments, and this may be the source of some of the deep-seated salt water.

The following table shows water analyses made by the United States Geological Survey:

[51] McNamee, R. L., The removal of iron from hard ground waters. Am. Water Works Assoc. Jour., vol. 21, no. 6, pp. 758-767, 1929.

Analyses of waters in Northwestern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

ARMSTRONG COUNTY

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst [a]
505	Drilled well ¾ mile northwest of Dayton; Freeport sandstone member	130	Oct. 9, 1929	[b]399	-------	8.89	[c]54	-------	[bd]30		94	227	[c]1.5	0	[e]250	-------	W.L.L.[g]
506	do.	128	do.	292	8.4	3.30	71	13	1.7	3.8	108	129	1.5	.08	231	50	do.[h]
509	Drilled well in Rural Valley, lower part of Allegheny formation (?)	300±	do.	[b]290	-------	-------	[c]1.0	-------	[bd]128		249	[c]2.0	33	.75	[e]1.0	-------	do.[gi]
510	Drilled well in Rural Valley; Pottsville formation (?)	400±	do.	445	25	.05	6.4	1.5	173	3.5	227	5.4	129	.40	22	-------	do.[gi]
519	Drilled well in Applewold; gravel of recent alluvium	44	do.	601	30	.12	124	21	22	4.0	170	259	27	4.7	396	-------	do.
521	Drilled well in Ford City; gravel of recent alluvium	57	do.	881	15	.08	190	26	51	7.2	292	331	59	33	582	-------	do.
522	do.	68	do.	399	15	.05	100	13	19	4.5	207	98	31	23	303	-------	do.

BEAVER COUNTY

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst [a]
309	6 drilled wells at Rochester; gravel of alluvium	40±	July 30, 1929	[b]408	-------	-------	[c]30	-------	[bd]89		88	[c]70	144	4.3	[e]158	-------	W.L.L.[g]
310	Drilled well in Monaca; gravel of glacial drift (?)	86	do.	[b]491	-------	-------	[c]36	-------	[bd]111		199	[c]120	61	50	[e]174	52	do.[g]
311	do.	85	do.	[b]526	-------	-------	[c]64	-------	[bd]66		252	[c]112	63	42	[e]303	54	do.[g]
312	Drilled well in Monaca; gravel of glacial drift	115	do.	[b]376	-------	-------	[c]64	-------	[bd]36		164	[c]120	34	12	[e]238	52	do.[g]
313	do.	98	do.	[b]516	-------	-------	[c]88	-------	[bd]77		108	[c]252	36	12	[e]243	52	do.[g]
314	do.(?)	96	do.	[b]417	-------	-------	[c]56	-------	[bd]73		222	[c]96	46	17	[e]202	53	do.[g]
315	Drilled well ½ mile southeast of Monaca; gravel of glacial drift	110	do.	[b]206	-------	-------	[c]42	-------	[bd]6		121	[c]55	17	.45	[e]180	56	do.[g]
318	10 drilled wells in Beaver; gravel of drift	20	Nov. 19, 1928	579	14	0.07	111	21	56	3.2	262	95	104	33	364	-------	F.
325	Drilled well 1¾ miles northeast of Industry; sbale of lower part of Allegheny formation	200	Oct. 6, 1928	3,826	10	10.98	40	12	1,415	23	862	3.3	1,868	1.5	149	52	do.

329–330	16 drilled wells in Baden; gravel of glacial drift	20–25	do.	256	13	4.03	44	9.3	24	3.5	92	81	30	.53	148	-------	do.
338	Drilled well in South Heights; sand and gravel of glacial drift	124	do.	425	18	.17	86	19	19	3.5	198	76	38	49	293	52	do.
1000	Spring at Morado Springs 2 miles north of Beaver Falls; sandstone of Pottsville formation	-------	do.	118	9.6	28.88	14	7.3	3.6	3.5	-------	51	22	.0	65	50	do.[a]
1001	Infiltration crib buried in sand and gravel in Ohio River at Monaca	-------	Nov. 20, 1928	696	20	1.11	98	15	114	7.0	177	132	190	11	806	-------	do.
1002	Ohio River at Monaca	-------	do.	230	5.6	3.7	31	9.2	19	2.6	-------	131	18	1.5	115	-------	do.[a]

CLARION COUNTY

431	Drilled well ½ mile northeast of Foxburg; Burgoon sandstone	150	Oct. 22, 1928	38	5.8	.03	3.8	1.8	3.8	1.2	6.0	6.9	2.5	12	17	50	S.K.L.
437	Drilled well 1 mile north of St. Petersburg; Kittanning sandstone member	150±	do.	106	8.5	2.73	24	7.5	2.6	1.7	103	12	1.0	.18	91	50	do.
438	Drilled well on north borough line of St. Petersburg; sandstone lower part of Allegheny formation	160	do.	[b]155	-------	2.08	[c]40	-------	[bd]20		102	[c]34	14	.0	[e]96	50	F.[g]
441	Drilled well in Knox; Burgoon sandstone	417	Oct. 23, 1928	227	8.4	3.53	28	5.7	46	3.2	140	23	44	.12	93	51	S.K.L.
442	do.	375±	do.	[b]245	-------	7.31	[c]16	-------	[bd]78		170	[c]28	40	.25	56	52	F.[g]
443	do.	160	Oct. 25, 1928	[b]283	-------	1.33	[c]10	-------	[bd]101		231	[c]35	26	.05	42	49	do.[g]
444	do.	156	do.	[b]106	-------	7.55	[c]10	-------	[bd]18		57	[c]30	10	.15	53	51	do.[g]
445	Drilled well in Shippenville; Connoquenessing sandstone member	255	Oct. 24, 1928	108	7.2	19.04	11	6.5	13	3.4	44	33	11	.15	54	49	do.
446	Drilled well in Fryburg; Connoquenessing sandstone member	208	Oct. 23, 1928	114	7.5	11.02	27	6.4	3.5	2.2	92	13	8.0	.05	94	50	do.[b]
449	10 drilled wells ¾ of a mile northeast of Clarion; Burgoon sandstone	135±	Oct. 19, 1928	384	8.2	2.83	35	8.0	94	3.4	282	8.6	70	.10	120	50	do.[h]
450	Drilled well 1 mile southeast of Clarion; Burgoon sandstone	300±	Oct. 18, 1928	[b]201	-------	6.82	[c]20	-------	[bd]52		118	[c]30	37	1.1	[e]67	52	F.[g]
456	Drilled well in Sligo; water from Burgoon sandstone at 120 feet	809	Oct. 19, 1928	[b]584	-------	3.02	[c]20	-------	[bd]196		232	[c]104	153	.13	[e]89	50	do.[g]
457	Drilled well (no. 2) in Sligo; Burgoon sandstone	310½	do.	447	9.5	.93	22	4.9	130	3.0	223	1.5	128	.05	75	50	S.K.L.
459	Dug well in Sligo; Brookville clay	14	do.	[b]157	-------	.20	[c]18	-------	[bd]21		10	[c]54	24	25	[e]73	56	F.[g]
461	Drilled well ¼ mile northwest of Rimersburg; Homewood sandstone member	260	do.	574	12	6.05	37	9.8	151	8.4	240	158	84	.05	133	53	S.K.L.
462	Drilled well ¼ mile northwest of Rimersburg; Vanport (?) limestone member	158	do.	[b]187	-------	3.40	[c]48	-------	[bd]30		168	[c]28	[c]4	.80	107	50	F.[g]
463	Drilled well 1½ miles east of East Brady; sandstone in middle of Allegheny formation	213	Oct. 11, 1929	267	9.9	.04	60	8.9	4.2	3.0	113	102	3.0	.10	186	50	W.L.L.

CLARION COUNTY—Continued

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst[a]
1003	Drilled flowing well in Sligo; yields 50± gallons a minute from Burgoon sandstone		Oct. 19, 1928	[b]407		.40	[c]24		[bd]150		254	[c]2	120	.10	53	50	F.[g]
1004	Spring in East Brady		Oct. 24, 1928	[b]80		.10	[c]12		[bd]6.0		20	[c]42	[c].8	2.2	[e]50	52	do.[g]
1005	Spring in Rimersburg		Oct. 19, 1928	[b]56		.0	[c]6		[bd]6.8		9.0	[c]16	10	6.9	[e]29	51	do.[g]
1006	Clarion River ¾ of a mile northeast of Clarion		do.	[b]171		1.50	[c]20		[bd]31		40	[c]70	25	.10	[e]73	65	do.[gn]

CRAWFORD COUNTY

88	Drilled well in Dicksonburg; glacial sand	155	Oct. 2, 1928	173	17	.16	29	7.6	24	1.9	153	11	12	.38	104	51	F.
96	Drilled well 1½ miles west of Mosiertown; glacial sand	132	do.	232	12	1.31	22	6.3	57	2.3	152	12	48	.75	81	49	do.
103	Drilled well 3 miles northwest of Cambridge Springs; glacial drift	81	Oct. 1, 1928	323	13	2.57	69	23	5.8	1.8	214	75	22	.05	267	49	do.
122–123	10 drilled wells 1 mile west of Titusville; glacial gravel	65–68	Sept. 28, 1928	140	12	.03	36	7.3	2.9	.9	114	19	5.8	2.1	120	49	do.[h]
141	6 drilled wells in Saegerstown; glacial gravel	63	Sept. 25, 1928	189	13	.17	45	8.7	3.5	1.0	125	39	3.6	9.5	148	48	do.
147–150	4 drilled wells 1½ miles northwest of Meadville; glacial gravel	80±	July 23, 1929	187	18	.01	42	9.0	4.1	2.2	142	30	8.0	.12	142	50	W.L.L.[m]
147–150	do.		July 22, 1929	[b]167			[c]30		[bd]8.7		144	[c]25	7.6	.14	[e]136	51	do.[gn]
165	Drilled well in Conneaut Lake; shale of Pocono group	50	do.	[b]241			[c]32		[bd]37		264	[c]10	4.4	.0	[e]152	49	do.[g]
175	Driven well 3½ miles south of Hartstown; shale of Pocono group	18	Oct. 2, 1928	148	16	.42	26	8.2	15	1.9	154	5.1	2.3	.38	99	51	F.
1007	Spring 2 miles southeast of Cochranton		July 23, 1929	[b]146			[c]32		[bd]11		125	[c]25	4	.06	[e]110	49	W.L.L.[g]
1008	Spring 1½ miles north of Conneaut Lake		Oct. 2, 1928	245	14	.06	66	16	1.7	.5	241	28	2.6	.38	231	49	F.
1009	Cussewago Creek 1 mile northwest of Meadville		July 22, 1929	[b]104			[c]28		[bd]13		86	[c]16	5.8	.13	[e]68	74	W.L.L.[g]

ERIE COUNTY

8	Drilled well 3½ miles east of Albion; shale of Chemung formation	36	Sept. 27, 1928	542	13	.42	32	14	160	6.3	406	3.2	115	.33	137	49	F.
9	Drilled well 5 miles east of Albion; shale of Chemung formation	54	July 22, 1929	[b]1,488	-------	-------	[c]18	-------	[bd]596		404	[c]3	716	1.4	[e]49	49	W.L.L.[g]
10	do.	50±	do.	[b]548	-------	-------	[c]11	-------	[bd]220		339	[c]2	164	.39	[e]34	48	do.[g]
14	Dug well 1½ miles northeast of Girard; sand and gravel of glacial drift	12	July 22, 1929	248	16	.12	58	12	3.4	4.0	171	41	6.0	14	194	49	W.L.L.[b]
27	Drilled well 4 miles south of Waterford; shale of upper part of Chemung formation	104	Sept. 25, 1928	177	15	.39	27	7.8	26	1.6	168	14	3.2	.96	99	49	F.
34	Drilled well in Waterford; gravel of glacial drift	100	Oct. 1, 1928	202	18	.30	25	8.3	37	2.2	162	5.1	28	.15	97	48	do.
38	Drilled well in Harborcreek; shale of Portage (?) formation	40	Sept. 27, 1928	137	6.0	.38	28	6.4	4.4	1.6	48	48	10	5.0	96	48	do.
54	Drilled flowing well 2½ miles northeast of Wattsburg; gravel of glacial drift	120	Oct. 2, 1928	140	15	.08	30	9.6	9.1	1.1	148	6.4	2.8	.05	114	49	do.
69	Drilled flowing well 2½ miles west of Corry; gravel of glacial drift	65	Sept. 26, 1928	133	13	.19	27	7.7	7.7	1.4	121	18	1.8	.15	99	49	do.
70	do.	130	July 20, 1929	[b]161	-------	-------	[c]56	-------	[bd]8.7		162	[c]14	3.6	.63	134	55	W.L.L.[g]
71	Driven well 2 miles west of Corry; gravel of glacial drift (inside well)	16	do.	[b]208	-------	-------	[c]58	-------	[bd]13		185	[c]31	4	2.8	[e]164	-------	do.[g]
72	do. (outside well)	16	do.	[b]138	-------	-------	[c]54	-------	[bd]5.5		139	[c]12	2.8	.75	[e]119	49	do.[g]
73	24 jetted wells just north of Corry; gravel of glacial drift	50±	do.	158	15	.05	36	6.4	3.0	3.5	130	19	3.6	1.2	116	-------	do.
1010	Spring 1½ miles southeast of North East	-------	Sept. 28, 1928	139	17	.02	33	7.3	.9	1.0	112	17	1.6	4.1	112	48	F.
1011	Hare Run just north of Corry	-------	July 20, 1929	[b]109	-------	-------	[c]30	-------	[bd]7.4		104	[c]10	4	1.1	[e]86	66	W.L.L.[g]

FOREST COUNTY

1012	Spring near Marienville, no. 2	-------	Oct. 12, 1929	[b]21	-------	-------	[c]1.5	-------	[bd]1.4	4.0	[c]6.0	[e].9	5.4	[e]12	-------	W.L.L.[g]	
1013	Spring near Marienville no. 1	-------	do.	[b]32	-------	-------	[c]1.0	-------	[bd]5.9	4.0	[c]6.5	4.2	11	[e]12	-------	do.[g]	

INDIANA COUNTY

540	Drilled flowing well in Clymer; sandstone of Pocono group	240	Oct. 10, 1929	478	7.9	.04	16	3.8	162	4.8	231	5.9	163	.35	56	51	W.L.L.[h]
1014	Spring no. 1 near Clymer	-------	do.	[b]198	-------	-------	[c]60	-------	[bd]8.5		175	[c]26	[c]2.0	8.8	[e]162	50	do.[g]
1015	Spring no. 2 near Clymer	-------	do.	[b]64	-------	-------	[c]17	-------	[bd]5.0		38	[c]15	[c]1.2	6.8	[e]43	50	do.[g]
1016	Spring near Marion Center	-------	do.	197	9.2	.06	36	11	.9	1.8	27	113	1.4	4.0	135	49	do.

JEFFERSON COUNTY

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst [a]
476	Drilled well half a mile east of Summerville; Pottsville formation	280	Oct. 11, 1929	1,155	8.5	1.69	49	12	368	12	197	8.1	593	1.9	172	-------	W.L.L.
477	do.	212	do.	[b]1,582	-------	2.71	[c]72	-------	[bd]548		167	[e]1.5	900	.20	[e]217	-------	do.[g]
492	Drilled well in Sykesville; shale of lower part of Conemaugh formation	171	Oct. 10, 1929	[b]739	-------	.40	[c]6.0	-------	[bd]296		545	195	5.8	1.5	[e]15	48	do.[g]
495	Drilled well in Sykesville; sandy shale of lower part of Conemaugh formation	204	do.	209	9.4	.04	40	10	14	2.4	116	70	2.1	.55	141	48	do.
502	Drilled well in Punxsutawney; upper part of Allegheny formation	170	do.	3,186	16	10.54	188	37	935	18	167	72	1,761	.65	622	-------	do.
503	do.	140	do.	[b]384	-------	42	[c]52	-------	[bd]33		21	225	32	.20	[e]225	-------	do.[g]
1017	Spring; ½ mile east of Summerville	--------	Oct. 11, 1929	[b]423	-------	-------	[c]74	-------	[bd]52		147	208	[c]1.5	5.1	[e]230	50	do.[g]
1018	Spring in Reynoldsville; yield 6 gallons a minute	--------	do.	[b]55	-------	-------	[c]9.0	-------	[bd]4.9		23	[c]10	[c]2.0	13	[e]32	-------	do.[g]
1019	Spring in Reynoldsville; yield 100± gallons a minute	--------	do.	59	6.1	.18	8.0	3.4	2.0	1.8	17	15	2.5	10	34	45	do.

LAWRENCE COUNTY

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst [a]
273	Drilled well ¾ mile south of New Wilmington; sandstone in lower part of Pottsville formation	297	Oct. 5, 1928	278	10	.40	43	12	49	3.6	302	14	2.5	1.6	157	50	F.[h]
283	Driven well ½ mile southwest of Mahoningtown; recent alluvium	16	do.	190	20	2.93	35	12	4.1	1.3	97	49	8.5	3.0	137	56	do.
289	Drilled well ¾ mile north of Princeton; Vanport (?) limestone member	134	Oct. 4, 1928	212	9.2	.61	38	16	19	5.0	232	13	2.4	.38	161	50	do.
293	Drilled well in Chewton; sandstone in upper part of Pottsville formation	90	Oct. 5, 1928	197	8.9	2.38	52	8.8	1.7	1.2	158	38	3.6	.05	166	50	do.
296	Drilled well in Enon Valley; glacial gravel	66	do.	269	18	.27	69	16	5.6	1.7	268	21	7.0	3.0	238	51	do.

MERCER COUNTY

187	Drilled well 2 miles southeast of Greenville; sandstone in lower part of Pocono group	354	Oct. 3, 1928	378	16	.28	22	7.8	110	3.7	272	14	68	2.9	87	50	F.
191	Drilled well in Sharpsville; sandstone of Pocono group	190	do.	466	18	.08	4.4	2.1	171	3.4	331	2.8	80	1.9	20	55	do.[a]
202	Drilled well in Harthegig; sandstone in lower part of Pottsville formation	68	do.	418	14	.49	98	25	11	3.2	326	74	21	2.0	348	50	do.
227	Drilled well in New Vernon; sandstone in lower part of Pottsville formation	56	do.	179	14	4.82	40	12	.5	2.9	128	33	8.2	.0	149	50	do.
234	Drilled well 1 mile southwest of Millbrook; sandstone in upper part of Pocono group	300	Oct. 4, 1928	227	22	.18	46	13	20	3.2	243	11	2.9	.05	168	50	do.
239	Drilled well in Grove City; sandstone in upper part of Pocono group	310	July 24, 1929	[b]258	-------	-------	[c]56	-------	[bd]46		217	[c]32	20	.38	[e]140	-------	W.L.L.[g]
241	do.	299	do.	[b]245	-------	-------	[c]31	-------	[bd]37		246	[c]15	12	.0	[e]153	51	do.[g]
243	do.	350±	do.	304	15	2.72	43	13	27	13	194	76	15	.81	161	50	do.
250	Drilled well ½ mile southwest of Mercer; glacial gravel	37	Oct. 4, 1928	138	17	1.18	32	6.3	2.5	1.2	99	21	2.1	3.5	106	50	F.
265	Drilled well in West Middlesex; sandstone in lower part of Pocono group (?)	316	July 24, 1929	850	17	.30	5.8	2.4	313	22	358	4.7	297	.30	24	52	W.L.L.
266	Drilled well 1 mile southeast of West Middlesex; sandstone in lower part of Pocono group (?)	307	Oct. 3, 1928	797	12	.07	7.8	2.8	299	3.8	408	4.4	250	1.6	31	53	F.

VENANGO COUNTY

387	Drilled well in Pleasantville; Connoquenessing (?) sandstone member	110	Oct. 12, 1928	[b]23	-------	.0	[c]2	-------	[bd]1.0		11	[c]2	6.0	.89	[e]18	50	F.[g]
389	Drilled well in Pleasantville; Olean (?) conglomerate member	270	Oct. 17, 1928	74	7.5	.54	12	4.8	3.9	1.3	39	14	7.5	.52	50	50	do.
406	Drilled well 2 miles southeast of Oil City; sandstone of Pocono group	63	Oct. 20, 1928	141	13	.03	30	4.5	9.7	2.0	91	15	19	.05	93	-------	do.
414	Drilled well in Franklin; gravel of recent alluvium	35	Oct. 26, 1928	[b]306	-------	.0	[c]64	-------	[bd]40		164	[c]80	32	4.2	[e]180	-------	do.[g]
416	Dug well 1½ miles west of Franklin; glacial gravel	38	Oct. 17, 1928	[b]151	-------	.0	[c]30	-------	[bd]20		108	[c]28	13	.94	[e]93	55	do.[g]
418	7 drilled wells 1½ miles west of Franklin; glacial gravel (?)	40±	Oct. 17, 1928	151	6.6	.02	36	7.6	6.5	1.5	109	26	12	.83	121	57	F.
419	Drilled well 1½ miles west of Franklin; gravel of recent alluvium	55±	Oct. 27, 1928	293	-------	3.02	[c]88	-------	[bd]50		141	[c]20	92	.10	[e]157	-------	do.[g]
1020	Spring 1½ miles southeast of Franklin; sandstone of Pocono group	--	Oct. 26, 1928	[b]225	-------	.0	[c]32	-------	[bd]57		69	[c]20	87	.50	[e]77	49	do.[g]
1021	Allegheny River 2 miles southeast of Oil City	--	Oct. 20, 1928	[b]105	-------	.20	[c]24	------	[bd]16		64	[c]20	14	.75	[e]59	-------	do.[g,h]
1022	French Creek 1½ miles west of Franklin	--	Oct. 17, 1928	[b]131	-------	.30	[c]40	------	[bd]15		114	[c]18	6.0	.69	[e]93	64	do.[g]

WARREN COUNTY

No.	Source	Depth of well (feet)	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Temperature (°F.)	Analyst [a]
341	Drilled well in Garland; gravel of glacial drift	86	Sept. 26, 1928	127	9.4	0.43	33	6.1	2.3	0.6	119	7.2	1.9	1.2	108	48	F
343	7 drilled wells in Youngsville; shale of upper part of Chemung formation	70	do.	136	11	.02	33	5.9	5.7	1.0	119	13	4.8	2.6	107	50	do.
358	Drilled well in Russell; gravel of glacial drift	51	do.	126	11	.76	33	7.1	1.7	.5	117	11	1.6	3.4	112	48	do.
360	Driven flowing well 1 mile southeast of Russell; gravel of recent alluvium	41	do.	124	12	.02	30	8.3	3.5	.7	125	7.8	1.2	2.3	109	48	do.
374	4 drilled wells 2 miles southeast of Warren; gravel of recent alluvium	70±	July 20, 1929	179	22	.08	39	7.0	6.9	2.2	130	19	14	1.2	126	50	W.L.L.
376	Drilled flowing well 3½ miles southeast of Warren; sandstone of lower part of Conewango formation	78	Sept. 26, 1928	154	14	.84	28	10	12	1.6	135	23	2.4	.0	111	48	F.

[a] F.=M. D. Foster. W.L.L.=W. L. Lamar. S.K.L.=S. K. Love.
[b] Calculated.
[c] By turbidity.
[d] Combined sodium and potassium.
[e] By soap method.
[f] Less than 5 parts per million.
[g] Partial analysis.
[h] See also analysis in another table.
[i] CO_3 15 parts per million.
[j] CO_3 22 parts per million.
[k] Acidity as H_2SO_4 8.8 parts per million.
[l] Acidity as H_2SO_4 6.0 parts per million.
[m] Sample taken after pumping 8 hours.
[n] Sample taken after pumping 5 minutes.
[o] CO_3 5.9.

The following table shows water analyses not made by the U. S. Geological Survey:

Analyses of waters in Northwestern Pennsylvania

(Parts per million. Numbers correspond to numbers in tables of well data for the counties)

ARMSTRONG COUNTY

No.	Source	Owner	Depth of well (feet)	Date of collection	Total residue (163°C)	Iron (Fe)	pH	Alkalinity	Chloride (Cl)	Nitrate (NO_3)	Total hardness (by soap method)	Analyst
506	Drilled well ¼ mile northwest of Dayton; Freeport sandstone	Dayton Borough	128	Feb. 7, 1927	146	2.0	6.7	106	1	0.1	90	P.D.H. [c]
508	2 drilled wells in Sagamore; sandstone in lower part of Conemaugh formation	Buffalo & Susquehanna Coal & Coke Co.	196	Nov. 17, 1926	450	.3	7.8	285	73	.3	170	do.

BEAVER COUNTY

319	5 drilled wells in Beaver; gravel of glacial drift	Beaver Borough	40	Apr. 6, 1926	650	0	7.2	240	100	5.6	330	do.
332	Drilled well in West Aliquippa; sand and gravel of glacial drift	Aliquippa Borough	41	1926	484	.03	5	-------	1.5	1.4	347	do. [d]
334	Drilled well in Aliquippa; sand and gravel of glacial drift	Woodlawn Water Co.	82	Apr. 17, 1928	680	.2	6.7	-------	39	2.0	[a]513	------
1023	Spring near New Galilee	Mrs. J. C. Andrews	--	Mar. 13, 1926	111	0	6.7	14	3	1.4	59	P.D.H.

CLARION COUNTY

446	Drilled well in Fryburg; Connoquenessing sandstone member	Fryburg Water Co.	208	----------	110	.5	6.3	56	6	.1	74	do. [c]
449	Drilled well ¾ mile northeast of Clarion; Burgoon sandstone	Clarion Water Co., well no. 1	135±	5.30 p.m., Dec. 11, 1925	355	4	7.2	265	38	-------	160	do. [c]
449	do.	do. well no. 2	135±	do.	346	1.4	7.4	235	53	-------	140	do. [c]
449	do.	do. well no. 3	135±	do.	381	1.0	7.4	210	80	-------	120	do. [c]
449	do.	do. well no. 4	135±	do.	391	.8	7.6	205	52	-------	120	do. [c]
449	do.	do. well no. 5	135±	do.	486	.5	7.6	145	170	-------	110	do. [c]
449	do.	do. well no. 6	135±	do.	356	.6	7.2	135	95	-------	84	do. [c]
449	do.	do. well no. 7	135±	do.	306	1.2	7.1	125	76	-------	100	do. [c]
449	do.	do. well no. 8	135±	do.	413	7	6.7	245	65	-------	170	do. [c]

CLARION COUNTY—Continued

No.	Source	Owner	Depth of well (feet)	Date of collection	Total residue (103°C)	Iron (Fe)	pH	Alkalinity	Chloride (Cl)	Nitrate (NO_3)	Total hardness (by soap method)	Analyst
449	do.	do. well no. 9	135±	do.	334	4	7.5	160	80	-------	110	do. [c]
449	do.	do. well no. 10	135±	do.	311	4	7.0	205	34	-------	160	do. [c]
449	10 drilled wells ¾ mile northeast of Clarion; Burgoon sandstone	Clarion Water Co., wells 1—10	135±	Feb. 9, 1925	320	2	7.0	150	80	.3	130	do. [c]
				May 31, 1925	475	5	6.9	210	78	11.0	140	do. [c]
449	do.	do.	135±	Nov. 6, 1925	390	2	7.0	200	72	.1	89	do. [c]
449	do.	do.	135±	8.15 p.m.,								
449	do.	do.	135±	Dec. 7, 1925	352	3	7.0	215	70	.2	220	do. [c]
449	do.	do.	135±	10.15 a.m.,								
449	do.	do.	135±	Dec. 8, 1925	360	3	6.9	213	69	.2	160	do. [c]
				8.15 p.m.,								
458	Drilled well in Sligo; Burgoon sandstone	Sligo Borough	313	Dec. 8, 1925	370	3	6.9	221	68	.1	160	do.
1024	Clarion River ¾ mile northeast of Clarion			May 10, 1926	323	.3	7.2	175	76	.1	63	do.
				Feb. 9, 1925	106	1	6.5	13	8	.3	46	do. [c]
1025	do.			Nov. 6, 1925	236	1.3	7.1	44	19	.3	84	do. [c]
1026	do.			Dec. 7, 1925	111	1.2	6.8	40	6	.3	47	do. [c]
1027	do.			Dec. 8, 1925	110	1.2	6.6	16	4	.3	42	do. [c]

CRAWFORD COUNTY

122–123	10 drilled wells 1 mile west of Titusville; gravel of glacial drift	Titusville city	65–68	Aug. 31, 1925	166	0	7.8	95	7	0.2	94	P.D.H. [c]
1028	Lubold Spring, 1 mile east of Cochranton	Cochranton Borough	-------	Jan. 16, 1926	158	.2	7.1	106	0	.4	81	do.

ERIE COUNTY

3	Drilled well in Albion; gravel of glacial drift	Bessemer & Lake Erie R. R.	30	Mar. 2, 1927	650	.5	7.4	300	30	.2	210	do.
3	do.	do.	30	Sept. 27, 1927	680	.6	7.4	290	37	.3	330	do.
5–6	5 drilled wells and 1 dug well 4 miles southeast of Albion; gravel of glacial drift	Albion Borough	20–30	May 26, 1929	190	.1	7.6	97	8.0	.4	110	do.
14	Dug well 1½ miles northeast of Girard; sand and gravel of glacial drift	Girard Borough	12	do.	253	0	7.6	150	4	1.6	160	do. [a]
15	Drilled well in Fairview; gravel of glacial drift	J. T. Raine	52	1928	230	.5	8.0	165	23	.1	140	do.
16	do.	do.	51	1928	180	0	8.0	110	3	1.5	160	do.
33	Drilled well in Waterford; gravel of glacial drift	Waterford Water Supply Co.	52	July 30, 1928	260	-------	-------	-------	46	0	71	W. W. Hilditch

FOREST COUNTY

1029	3 drilled wells in West Hickory; sandstone of Pocono group	West Hickory Tanning Co.	75	July	6, 1917	252				29.2		183	A. W. Hoppenstedt
1030	do.	do.	75	Apr.	14, 1927	288	.15			29.2		203	do.
1031	Allegheny River at West Hickory			July	6, 1917	152				11.7		38	do.
1032	do.			Apr.	14, 1927	180	4.6			14.7		45	do.

INDIANA COUNTY

529	Drilled well in Graceton; sandstone in lower part of Allegheny formation	Graceton Coal & Coke Co.	385			340	.3	7.8	157	8	.2	210	P.D.H.
539	Drilled well in Clymer; sandstone of Pocono group	Clymer Citizens Water Co.	215			460	.6	7.3	163	160	0	59	do.
540	do.	do.	240			490	.3	7.5	190	177	0	57	do. [c]
1033	Two Lick Creek near Indiana			Dec.	23, 1927	284	12.8	4.8		6		[a]124	E. C. Trax

LAWRENCE COUNTY

272	Drilled well ¼ mile south of Wilmington; sandstone in lower part of Pottsville (?) formation	New Wilmington Water Co.	250	Jan.	30, 1926	286	.3	7.2	257	2	.1	150	P.D.H.
273	do.	do.	297	Jan.	16, 1926	278	.1	7.3	270	4	.1	160	do. [c]

MERCER COUNTY

185	Drilled well in Greenville; Pocono group	Bessemer & Lake Erie R.R.	210	Mar.	29, 1926	320	.2	9.0	211	50	2.0	13	P.D.H.
1034	Drilled well in Sharpsville	Shenango Furnace Co.	305	June	25, 1926	585	.2	7.6	195	14	.1	340	do.
1035	Drilled well in Ferrona	Erie R. R.		Sept.	28, 1927	260	.3	8.0	170	30	.1	63	do.
1036	Spring in Hickory Township	Michael Bobley		May	3, 1926	135	0	6.2	35	2	1.5	71	do.
1037	Springs near Stoneboro	Stoneboro Borough		Sept.	30, 1927	100	0	6.7	50	1	2.0	60	do.

VENANGO COUNTY

410	Dug well (no. 1) 2 miles southeast of Oil City; gravel of glacial drift	Oil City		May	5, 1923	119	.25			13	.2	43	------
411	Dug well (no. 2) 2 miles southeast of Oil City; gravel of glacial drift	do.			do.	130	.10			15	.2	46	------
1038	Allegheny River 2 miles southeast of Oil City				do.	80	trace			9	.3	25	------ [c]

[a] Calculated.
[b] Pennsylvania Department of Health.
[c] See also analysis in other table.
[d] Ca 109, Mg 8.1, SO_4 150.

DESCRIPTION BY COUNTIES.

EXPLANATION OF DATA.

The information pertaining to most of the domestic supplies listed in each county was obtained from well drillers. These wells were located on topographic maps from the descriptions given by the drillers. Many of the wells were visited, but it was not possible in the time available to visit each well and check its location. It may be therefore, that some of the wells are not accurately located.

Most of the wells listed in the tables are drilled wells covered with pumps, so that it was not generally possible to make measurements of depths and water levels. Many of the data for domestic supplies are therefore taken from statements of drillers or owners. Although some of the drillers who were interviewed have kept very adequate written records, many of them had only meager notes, and some of them none at all. The figures on depth to water level are probably the least accurate of all given in the tables, as most of the drillers relied on memory in supplying this information.

The data pertaining to most of the industrial and municipal supplies were in general taken from records of companies or municipalities and are probably more accurate than the figures given for domestic supplies.

Many of the well drillers in describing the formations which they encounter use such terms as "slate" and "slate and shells." Their distinction between shale and "slate" is based on the cutting action of the bit. The "slate" cuts clean, whereas the shale has a tendency to pack or gum up. In the geologic sense they are both shale, and that usage is therefore followed in this report. The description of "slate and shells" seems to indicate a thin-bedded sandstone or possibly alternations of shale and thin-bedded sandstone.

In determining the geologic horizon of the water-bearing bed the county maps of the Second Geological Survey of Pennsylvania and the United States Geological Survey folios, so far as available, were used in conjunction with the individual well logs.

No differentiation has been made in the tables between the glacial deposits of different ages because the water-bearing properties of these materials seem to be relatively independent of their age. In a few wells recent alluvium has been listed as the water-bearing material. This alluvium has the same general hydrologic properties as the glacial deposits and is in fact glacial outwash that has been rehandled by flood waters in recent times.

Where figures for yield are given they are thought to represent very closely the true yield. They represent either measurements made by the writer or pumping tests made and recorded at the time the well was completed. Figures for drawdown represent direct measurements, readings of vacuum gages where wells are pumped by suction, or readings of starting and operating pressures where wells are pumped by air lift. Wells recorded as having "small" or "large" drawdowns are wells that were reported as being "weak" or "strong" wells respectively.

ARMSTRONG COUNTY

GENERAL FEATURES

Armstrong County lies in the southeastern part of the area covered by this report and contains 653 square miles. In 1930, according to the United States Census Bureau, its population was 79,298. Two towns have more than 5,000 inhabitants—Kittanning, with 7,808, and Ford City, with 6,127. In 1930 there were 92 manufacturing establishments and 42 mines in the county.

Armstrong County is drained by the Allegheny River and its tributaries. The valley walls of the major streams are moderately steep in places. The county as a whole has a mature topography, being minutely dissected by many small streams. Small flat areas occur only along the larger streams and in the upland regions. The highest point in the county lies about 1½ miles northeast of Pierce post office, in Redbank Township, near the Jefferson County line, where a knob rises more than 1,740 feet above sea level. About 4 miles south of this high point another knob has an altitude of 1,707 feet above sea level. Only one other point in the county has an altitude of more than 1,700 feet, a knob about a mile northeast of Muff, in Wayne Township, which is more than 1,720 feet above sea level. The lowest point in the county is in the Allegheny Valley at the southwest corner, where the altitude is less than 740 feet. The total relief of the county is therefore about 1,000 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

No part of Armstrong County was covered by glaciers during the ice invasion from the north. The Allegheny Valley, however, carried waters which had resulted from the melting of the glaciers, and these waters deposited glacial outwash along the whole length of the valley through Armstrong County. (See plate 4.) This valley carried water from at least two separate ice sheets, the Illinoian and the Wisconsin. The remnants of outwash material found 200 to 300 feet above the present river are thought to be of Illinoian age, and the lower deposits, up to about 60 feet above the river, are thought to be of Wisconsin age, though the material near the stream is probably recent alluvium. The river, in most places, is flowing on alluvium 30 feet or more above the rock floor. An oil well on the south side of the Allegheny River about 1 mile west of the mouth of Redbank Creek started about 10 feet above the river and penetrated 86 feet of unconsolidated material before striking bedrock. The altitude of the bedrock at this point is therefore about 736 feet above sea level. A well at Ford City commencing about 20 feet above the river is 68 feet deep and does not encounter bedrock. The rock floor is therefore less than 732 feet above sea level at this locality. The high-level Illinoian gravel is generally about 15 to 30 feet thick, but in a few places it attains greater thickness. Across the river from Templeton the gravel is about 90 feet thick and the base of the deposit about 160 feet above the river.[52] The areas of occurrence of the older gravel are small and patchy, whereas the younger deposits extend in long stretches along the river. These younger deposits yield large quantities of hard water to properly constructed

[52] Butts, Charles, and Leverett, Frank, U.S. Geol. Survey Geol. Atlas, Kittanning folio (no. 115), p. 9, 1904.

shallow wells (well 521). A number of drilled wells in West Kittanning that adequately supply domestic needs range in depth from about 45 to 80 feet. A few dug wells are also in use, but they are not considered so desirable. Kittanning is located on a gravel flat, and most of the wells, therefore, derive water from the underlying gravel. Small, more or less isolated areas of the Carmichaels formation occur along Crooked, Cowanshannock, and Mahoning creeks, but the beds are generally thin.

ROCK FORMATIONS[53]

The rocks exposed at the surface in Armstrong County extend from about 200 feet above the base of the Monongahela formation down to and including more than 200 feet of the Pocono group. In the south half of the county the Conemaugh formation lies at the surface except in the valleys of the larger streams. The Monongahela formation is present only in a small area in the southern part of the county. The Allegheny formation lies at the surface over most of the northern part, although the highest ridges are capped by small areas of the Conemaugh formation. The Allegheny River, from the northwest corner of the county down to a point a little below the mouth of Mahoning Creek, has cut its valley into the Pottsville formation and in much of that distance also exposes part of the Pocono group. Mahoning Creek through most of its course across the county exposes the Pottsville formation and near its mouth and for a few miles south of Eddyville also exposes the upper part of the Pocono. From the mouth of Redbank Creek nearly to New Bethlehem the Pottsville and the Pocono are exposed.

The following generalized section is compiled from data given by Butts and Stone:

Generalized section of rocks exposed in Armstrong County

Age	Formation	Thickness (feet)	Character and water-bearing properties
Pennsylvanian.	Monongahela formation.	200±	Chiefly shale but contains also thin limestone beds and locally developed sandstone beds. Areal distribution too small to be of use as a source of ground water.
	Conemaugh formation.	650±	Chiefly shale of various colors—green, drab, and red the most pronounced—interstratified with beds of coarse sandstone, which are fairly persistent but which in places lose their distinctive character. Contains also a few thin beds of limestone and coal. Sandstone members generally yield moderate supplies of somewhat mineralized water.
	Allegheny formation.	300–360	Shale with thick beds of sandstone, beds of limestone with associated iron ores, and several valuable coal seams and beds of clay. Sandstone members yield moderate to good supplies of somewhat mineralized water.
	Pottsville formation.	120–140	Coarse sandstone or conglomerate, generally thick-bedded, with intermediate beds of shale carrying clay and coal. Sandstone members yield good supplies of somewhat mineralized water. Where the formation is deeply buried, the water may be salty.
	Unconformity		
Mississippian	Pocono group: Burgoon sandstone.	[a]225	Coarse, massive sandstone broken by shale. Yields good supplies of somewhat mineralized water. Where the sandstone is deeply buried, the water will probably be salty.

[a] Exposed.

[53] The descriptions given here are taken mainly from Charles Butts (Economic geology of the Kittanning and Rural Valley quadrangles, Pa.: U.S. Geol. Survey Bull. 279, 1906); and R. W. Stone, U.S. Geol. Survey Geol. Atlas, Elders Ridge folio (no. 123), 1905.

Monongahela formation—The small areas of the Monongahela formation in this county form parts of a larger area which lies mostly in Indiana County and is described under that county.

Conemaugh formation—The total thickness of the Conemaugh formation in Armstrong County is about 600 to 700 feet, but the upper part of the formation is present only in the southern part of the county, adjacent to the area of the Monongahela formation. The formation is composed mostly of shale, but in places massive sandstone beds are present. The sandstone beds are all irregular, both in thickness and in lithologic character, and are not easily distinguished from one another. At least four different beds of sandstone have been recognized in different parts of the county. In the southern part of the county the Connellsville sandstone, which lies 40 to 80 feet below the top of the Conemaugh formation, is present in some places as a massive rock. Its area of occurrence is small and is restricted to the vicinity of the Monongahela outcrops. The Morgantown sandstone, which lies about 500 feet above the base of the Conemaugh formation, is a conspicuous massive sandstone in numerous localities but is also poorly developed in many places. About 150 feet above the base of the Conemaugh is a thin, unimportant coal bed, which probably represents the Bakerstown coal. In places thick sandstone beds are present both above and below this coal. The upper sandstone is the Saltsburg, and although the lower appears to be the Buffalo sandstone of the Butler County area to the west, Butts[54] is of the opinion that both sandstones together represent the true Saltsburg. In places the upper sandstone is 60 to 80 feet thick and the lower one 40 to 50 feet thick. The base of the Mahoning sandstone usually lies near the Upper Freeport coal, though in places the two are separated by as much as 10 feet of shale. The sandstone has locally a thickness of more than 40 feet but is usually not so thick. It ranges from a very shaly rock to a massive sandstone. The sandstone members of this formation, where massive, generally yield moderate supplies of water to drilled wells. The water may contain considerable dissolved mineral matter and may be somewhat high in iron.

Allegheny formation—The Upper Freeport coal, the top of which marks the top of the Allegheny formation, is rather persistent throughout the area where it has not been eroded away. It attains a thickness of 4 feet in some places but in many places is not of workable thickness or quality. Between the Upper and Lower Freeport coals occurs an interval of 20 to 60 feet which in most places is occupied by shale. However, in some places the shale disappears and the Butler sandstone, massive and coarse-grained, occupies all or part of the interval. In the western part of the county the interval is smaller than it is in the eastern part. The Lower Freeport coal is more than 4 feet thick in some localities but is probably less than 2 feet thick over most of the county. Between the Lower Freeport coal and the Upper Kittanning coal 40 to 50 feet of shale occurs but in places the Freeport sandstone becomes prominent and fills most of the interval. This sandstone is more persistent than any other sandstone in the Allegheny formation. In some places it is a fine-grained flaggy rock, but in many places it is massive and coarse-grained or conglomeratic. The sandstone is well developed in the region around Worthington, in the

[54] Butts, Charles, op. cit., p. 41.

southern part of Sugar Creek Township, along the lower portions of Mahoning Creek, and in parts of Boggs, Rayburn, and Valley townships. It is massive and 50 feet or more thick in some localities.

The Lower, Middle, and Upper Kittanning coals are all locally present in this area. The middle coal is rather persistent, though not of workable thickness in most places. The Lower Kittanning coal is persistent, particularly in the northwest quarter of the county, and is generally 3 to 4 feet thick. The intervals between the Kittanning coals are usually occupied by shale, though in places a heavy sandstone occurs between the Lower and Middle coals. The Lower Kittanning coal generally lies 30 to 40 feet above the Vanport limestone, though it may be as much as 50 feet or as little as 15 feet. In some places this interval is almost completely occupied by the massive coarse-grained Kittanning sandstone, but in others the sandstone is absent or thin-bedded. Here and there the Kittanning sandstone cuts out the Vanport limestone, as at Greendale, in Valley Township. The sandstone is prominent along the Allegheny River from Mosgrove to Ewing and in the vicinity of Rimer. The Vanport limestone in Armstrong County has the same general characteristics as it has in the area to the west. It is absent in parts of the county but probably has an average thickness of about 8 feet. Exposures and well records show it to be 22 feet thick in numerous places. It is a bluish-grey fossiliferous rock usually containing about 90 percent of calcium carbonate. About 15 to 25 feet below the Vanport limestone is the Clarion coal and below it in some localities a massive sandstone as much as 50 feet thick. About a mile above the mouth of Cowanshannock Creek the sandstone is about 40 feet thick, and near West Winfield it is massive and about 50 feet thick. The Brookville coal lies about 10 to 20 feet above the top of the Pottsville formation, the interval being occupied by shale and clay.

In the region around Dayton very few dug wells are in use. Drilled wells, most of which are less than 100 feet deep, generally yield ample supplies for domestic use. These wells are reported to end in the upper part of the Allegheny formation.

The following is a log of a well 2 miles southwest of Worthington:

Log of well 517, 2 miles southwest of Worthington.

	Thickness (feet)	Depth (feet)
Weathered material	20	20
Sandstone; considerable water at 55 feet	40	60
Shale	20	80
"Slate"	31	111
Coal (Lower Kittanning)	3	114
Fire clay	6	120
Shale and sandstone; Kittanning sandstone, main water producer, at 135 feet	29	149
Limestone (Vanport)	19	168
"Slate"	14	182
Fire clay	5	187
Shale	38	225
Sandstone, Clarion sandstone, water at 247 feet	38	263
Shale	23	286
Sandstone	14	300

The sandstone members of the Allegheny formation are some of the best water-bearing beds in the bedrock of the county. Where massive,

they generally yield good supplies of water to drilled wells. The water is usually somewhat mineralized and in many places may be high in iron.

Pottsville formation—The Homewood sandstone is the top member of the Pottsville formation and lies about 100 feet below the Vanport limestone. It is usually a gray massive rock about 40 feet thick, though in places it loses its massive character and becomes thin-bedded or shaly. The Mercer shale member, about 20 to 40 feet thick, separates the Homewood and Connoquenessing sandstones and is made up mainly of dark sandy shale but contains one or more thin coal seams and in places thin beds of limestone.

The Connoquenessing sandstone member, which marks the base of the Pottsville formation, is massive, coarse, gray to white, and about 40 feet thick. In places it is thin-bedded or shaly but commonly is massive and conglomeratic. The base of the Connoquenessing lies on the eroded surface of the Pocono. In the north half of the county, where the Pottsville formation is not too deeply covered by younger formations, good supplies of somewhat mineralized water can usually be obtained. In the southern part of the county, however, younger water-bearing beds are likely to be encountered before the Pottsville is reached. There is also likelihood of finding salt water in the Pottsville where it lies deeply buried.

Pocono group—The unconformity between the Pennsylvanian and Mississippian series in Armstrong County brings the Connoquenessing and Burgoon sandstones together. The contact of the two sandstones is not easily determined, because both rocks are very similar and the unconformity is usually slight. The Mauch Chunk formation and the Loyalhanna limestone, which lie above the Pocono group in the area to the east, are not present in this county, having been eroded away before the Pottsville formation was deposited. The Burgoon sandstone (Mountain or Big Injun sand of drillers), the only part of the Pocono group exposed in the county, is usually a thick-bedded gray to greenish rock, but in places it contains beds of shale or shaly sandstone. The Burgoon sandstone generally yields good supplies of moderately mineralized water, but where it is deeply covered by younger formations it is likely to contain salt water.

Structure—The rocks of Armstrong County have been folded into a series of low anticlines and synclines, the axes of which trend roughly northeastward. These axes do not have the form of a straight line, as assumed by the geologists of the Pennsylvania Second Geological Survey, but curve in different directions with wavelike courses. There is a general regional dip of the rocks to the southwest, so that the axes of the folds pitch to the southwest, and because of this dip older and older rocks are exposed along the axes toward the northeast. In northwesterly and southeasterly directions the rocks dip away from the anticlinal axes and toward the synclinal axes; the highest dips probably do not exceed about 4°. The axis of the Bradys Bend syncline passes through the town of East Brady, trending a little north of east to the vicinity of Lawsonham, where it curves more to the north and leaves the county. The fold lying next to the southeast is the Kellersburg anticline. The axis enters the county about a mile north of West Winfield, crosses Buffalo Run about half a mile above Craigsville, and continues in a northeasterly direction to a point about 2

miles north of Cowansville, where it curves almost due east and crosses the Allegheny River about a mile below Rimer. From this point it continues in an almost straight line until it leaves the county at about the northwest corner of Mahoning Township. This is the most prominent fold in the county, and along its flanks occur the steepest dips in the county. Between the Kellersburg anticline and the Allegheny River below Mosgrove two minor folds are present—the Boggsville syncline and the McHaddon anticline. They both die out to the northeast before crossing Limestone Run a mile or so above its mouth. The next prominent fold lying to the southeast is the Fairmount syncline. South of Ford City its course has not been mapped in detail, but northeast from that city it extends in a slightly curving course to the northeast corner of Pine Township, where it curves somewhat to the east and then to the north and leaves the county about a mile east of New Bethlehem. The Greendale anticline lies next to the southeast. The axis begins about 2½ miles northwest of Cochran Mills and extends northeastward in a curving course, passing near Shay, Blanket Hill, Greendale, Muff, and Belknap. The axis of the Apollo syncline starts a little southwest of Cochran Mills and extends northeast to a point about half a mile northeast of Blanco, where it dies out. The axis of the Roaring Run anticline passes near Equitable, Sandy Plain, and Girty and dies out about a mile west of Blanco. The axis of the Elders Ridge syncline lies in Indiana County about half a mile from the Indiana-Armstrong County line, which it parallels nearly to West Lebanon but beyond that point it curves to the east and has little effect on the rocks of Armstrong County.

GENERAL GROUND-WATER CONDITIONS

Armstrong County is fairly well supplied with ground water. Small springs are numerous on steep slopes, and they are utilized in many places for domestic supplies. However, they fluctuate considerably with the season and are therefore not very trustworthy sources of supply. There are many old dug wells in the county, but most of them have been abandoned and replaced by drilled wells.

The gravel in the Allegheny Valley appears to be the best producer of large quantities of water. The sandstones of the county can usually be relied upon to yield moderate quantities of water, though in some places, especially in areas where they are thin-bedded or shaly, they yield little or no water. A member of any formation may have different water-bearing properties in different localities because the beds may change from sandstone to shale in short distances.

In some parts of the county artesian conditions exist, though in most localities the artesian head is not sufficient to produce flowing wells. In the table of drilled wells in Armstrong County wells 505, 506, 518, 523, and 524 have static water levels that stand higher than the depth at which the water was encountered. More complete data on some of the other wells listed in the table would no doubt also show artesian conditions. Wells 523 and 524 lie southeast of the axis of the Fairmount syncline. Wells 505 and 506 lie southeast of the axis of the Greendale anticline. Well 518 lies between the axes of the Kellersburg anticline and the Boggsville syncline. Artesian wells, some of which may flow, are to be expected along all the synclines in the county.

QUALITY OF WATER

Analyses of waters from Armstrong County are given on foregoing pages. Water from sandstone is in general high in iron, in some beds so high that unless the water is treated for partial removal of the iron it will not be satisfactory. The water from wells drilled into the glacial outwash along the major valleys has in general less iron than the water from the sandstone, but it is considerably harder than the water from either sandstone or shale. The chief problem relating to quality of water for the county as a whole is that of the removal of iron. Methods of removing iron are described on another page.

Deep drilling is not advisable because of the likelihood of encountering salt water. In the early days salt was obtained by evaporating water from deep wells in the southern part of the county along the Kiskiminetas River.[55] The water was pumped from wells that ended in the Pocono group.

PUBLIC SUPPLIES

In the following table are listed 21 public water supplies in this county. Of these supplies, 8 are derived from streams, 2 from springs, and the rest from drilled wells. Ford City, with an average daily consumption of about 500,000 gallons, uses the largest quantity of ground water in the county. There appear to be ample quantities of ground water to meet present and prospective needs, although additional wells will no doubt have to be sunk to supply the increased demands of future developments. Some of the ground water in use is high in iron. As a rule the ground-water supplies do not require chlorination.

[55] Platt, W. G., Pennsylvania Second Geol. Survey Rept. H[5], pp. 10, 17, 260, 1880.

Public water supplies in Armstrong County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Apollo	3,406	Apollo Waterworks Co.	Beaver and Gilkerson Runs			Direct		700,000		Chlorine, lime, filter
Applewold	477	Municipal	Two drilled wells	Recent alluvium	Deep well pumps	do.[a]	25,000	15,000		None[bc]
Cadogan		Allegheny River Mining Co.	Allegheny River			do.	170,000			
Chickasaw		do.	Three drilled wells		do.	do.	26,000	8,000		None
Dayton	857	Municipal	Two drilled wells	Freeport sandstone	do.	do.	65,000	35,000	85	do.[b]
Ford City	6,127	do.	do.	Recent alluvium	Turbine pumps	Gravity	1,500,000	500,000	80	Chlorine gas, lime and soda, softened[b]
Freeport	2,772	Freeport Waterworks Co.	Allegheny River			do.	450,000	800,000		Chlorine gas, alum, filter
Furnace Run, no. 1		Allegheny River Mining Co.	do.			Direct[a]				
Furnace Run, no. 2		do.	Drilled well		Deep well pump	Gravity	20,000	1,000		
Johnetta		Johnetta Brick & Coal Co.	Stream			do.	None	25,000		
Kittanning	7,808	Armstrong Water Co.	Allegheny River			do.	1,200,000	1,250,000±		Chlorine, aluu, filter
Manorville	608		Spring			Direct				
Nu Mine		Cowanshannock Coal & Coke Co.	Drilled well		Deep well pump	Gravity	50,000±			
Parker City	902	Parker Water Co.	Allegheny River			do.	27,000	75,000		Chlorine, alum, filter
Rosston		T. A. Heilman	Three springs			do.	3,000	1,500	60	None

Rural Valley	948	Municipal	Two drilled wells	Lower part of Allegeny or upper part of Pottsville	Air	do.	35,000	30,000	90	do.[b]
Sagamore		Buffalo & Susquehanna Coal & Coke Co.	Four drilled wells	Lower part of Conemaugh and upper part of Allegheny	do.	Direct[a]	160,000	120,000		Aerated[b]
Seminole		Allegheny River Mining Co.	Drilled well	Allegheny formation (?)	Deep well pump	Gravity	20,000	15,000		None
South Bethlehem	469		From Citizens Water Co. of New Bethlehem							
Worthington	661	Pure Water Co.	Two drilled wells	Allegheny formation (?)	Deep well pump		20,000			
Yatesboro		Cowanshannock Coal & Coke Co.	Four drilled wells			Gravity	50,000±			

[a] Excess to reservoir. [b] See analysis. [c] One well held in reserve.

Drilled wells in Armstrong County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to water-bearing bed (feet)	Character of water bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[c]	Remarks
505	¼ mile northwest of Dayton	Dayton Borough, well no. 1	Valley	1,320	130	8	110	Sandstone	Freeport	30	15	PS	60 feet south of well 506. See analysis. This well flowed when first drilled; yield when pumped 69 gallons a minute.
506	do.	Dayton Borough, well no. 2	do.	1,320	128	8	110	do.	do.	30	15	do.	60 feet north of well 505. See analyses. Yield when pumped 75 gallons a minute.
507	Sagamore	Buffalo & Susquehanna Coal & Coke Co.	do.	1,100	202	8	-------	----------	Upper part of Allegheny	37	30	do.	----------
508	do.	do.	do.	1,100	196	10	44	Sandstone	Lower part of Conemaugh	23	45	do.	2 similar wells; water also encountered at 39 feet. See analysis.
509	Rural Valley	Rural Valley	do.	1,100	300±	6	-------	----------	Lower part of Allegheny (?)	-----	------	do.	About 70 feet from well 510. See analysis. Drawdown of 40± feet pumping 25± gallons a minute.
510	do.	do.	do.	1,100	400±	6	-------	----------	Pottsville	-----	------	do.	About 70 feet from well 509. See analysis. Drawndown of 40± feet pumping 25± gallons a minute.
511	Seminole[b]	Allegheny River Mining Co.	----------	1,350	502	6¼	-------	Sandstone	----------	50	52(?)	do.	Pumps about 15,000 gallons a day.[b]
512	Mosgrove	Earl Shea	Hillside	940±	100	-----	-------	----------	Middle part of Allegheny	-----	------	D	Moderate quantity of water.
513	3 miles northwest of Kittanning	Allegheny River Mining Co.	Divide	1,200±	303	6¼	-------	----------	Lower part of Allegheny	122	------	Ind.	----------
514	3 miles northwest of Ewing	do.	Valley	1,130	80	8	80±	----------	Upper part of Allegheny	-----	------	do.	Large supply of water reported.
515	do.	do.	Hillside	1,190	204	-----	-------	----------	Lower part of Allegheny	-----	------	do.	do.
516	Worthington	Sam Welton	Crest of ridge	1,200	77	-----	-------	----------	Upper part of Allegheny	-----	------	D	Small supply of water.
517	2 miles southwest of Worthington	Pittsburgh Limestone Co.	Hillside	1,080±	300	6¼	135	Sandy shale	Kittanning sandstone	-----	------	Ind.	See log of well in text.

518	do.	do.	Valley --	980	355	-----	55	Sandstone (?)	Clarion (?)	-----	50	do.	Water also encountered at one deeper horizon.
519	Applewold ----	Applewold Borough ----------	Terrace -	800	44	10	-------	Gravel	Recent alluvium	44	10±	PS	About 10 feet from well 520. See analysis.
520	do.	do.	do.	800	37	10	-------	do.	do.	37	10±	do.	About 10 feet from well 519; this well held in reserve.
521	Ford City ----	Ford City ------	do.	800	67	24	-------	do.	do.	57	17	do.	Sand and loam 15 feet, gravel 8 feet, fine sand 6 feet, gravel 28 feet; 13-foot drawdown pumping 800 gallons a minute for 5 days. See analysis.
522	do.	do.	do.	800	68	24	-------	do.	do.	68	17	do.	Log similar to that of well 521. See analysis.
523	3 miles southeast of Ford City -------	----------	Hillside -	990	160	8	-------	----------	Middle part of Allegheny ----	-----	-----	-----	Flowed about 40 gallons a minute until well 524, a short distance away, was drilled; well 523 ceased flowing and well 524 started to flow about 40 gallons a minute.
524	do.	----------	do.	990	250	8	-------	----------	Lower part of Allegheny ----	-----	------	-----	This well and well 523 together supplied 1,000,000 gallons a day for 6 weeks, with drawdown of 94 feet; water reported to be soft.
525	2½ miles north of Avonmore	S. B. Alshouse	Hilltop --	1,400±	-------	-----	500±	----------	Upper part of Allegheny ----	-----	------	-----	Old gas well; fresh water between 481 and 534 feet and between 549 and 558 feet.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] PS=Public Supply; D=Domestic; Ind.=Industrial.

BEAVER COUNTY

GENERAL FEATURES

Beaver County lies in the extreme southwestern part of the area described in this report and covers 429 square miles. The point at which the Ohio River enters the southeastern part of the county lies about 15 miles northwest of Pittsburgh. According to the Federal Census of 1929 there were 208 manufacturing establishments in the county. The industrial development is, for the most part, restricted to the valleys of the two major streams—the Ohio and Beaver Rivers—along which there is an almost unbroken chain of industries.

The population of the county in 1930, according to the Federal Census Bureau, was 149,062. Five of the twenty largest cities of the area covered by this report are in Beaver County; their population aggregates 82,166 and ranges from 27,116 in Aliquippa to 7,726 in Rochester.

The county is drained by the Ohio and Beaver Rivers, together with their small tributary streams. Ohio River for a distance of 32 miles from Sewickley, Pa., to East Liverpool, Ohio, falls 20 feet, giving it a gradient of about 0.6 foot to the mile in its course through the county. Beaver River from its mouth upstream to the dam at Beaver Falls, a distance of about 4 miles, has a gradient of 11.5 feet to the mile. Upstream from the dam to the north county line its gradient is 2.9 feet to the mile. Raccoon Creek enters the county from the south and flows northward over a very meandering course (just twice the straight distance) until it joins the Ohio just below Dam 6. Its gradient is 8.2 feet to the mile.

There is almost no flat land in Beaver County with the exception of a few narrow terraces paralleling the major streams and numerous rather small upland flats. The small streams are so numerous and have cut their valleys so deep in places that the county is essentially a region of valleys with small flat-topped ridges at the crests of the divides between the streams. These upland flats, over most of the county, lie between 1,200 and 1,300 feet above sea level.

The maximum relief of the county is about 680 feet—that is, the highest point is about 680 feet above the lowest point. Less than a mile southwest of the Ohio River at Midland a hill whose altitude is about 1,360 feet stands more than 680 feet above the river.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

Only a small area in the northwestern part of Beaver County was covered by ice during the glacial epoch. (See pl. 4.) However, the melting of the ice sheet produced water that drained away from the ice margin, carried with it silt, sand, and gravel, and deposited these materials, partly filling up the valleys. This valley filling has since been entrenched by the streams, leaving now only terraces composed of more or less stratified material.

Nowhere in Beaver County is the glacial boundary marked by a prominent terminal moraine, as is common in the counties to the northeast. Instead, it is rather an indefinite line, determined only by carefully mapping the occurrence of erratic material.

The till, or glacial material that was deposited directly from the ice without much sorting by water, is thin in this county, in many places only a scattering of drift pebbles being present. The valley of Little Beaver Creek, which lies within the glacial boundary, is filled with more or less stratified sand and gravel. (See well 297.)

The age and position of the gravel terraces of northwestern Pennsylvania are described on page 29. The older gravel, which lies highest above the streams, is generally thin and of patchy occurrence. The younger glacial gravel, together with the recent alluvium, is much more extensive and attains greater thickness. Ten wells were recorded along the Ohio Valley which show a thickness of 110 feet or more of valley filling. One of these wells, about 1 mile southwest of Bellowsville (well 321), passes through 167 feet of sand and gravel and yet does not reach bedrock. A well in Beaver Falls, 92 feet deep (well 304) likewise does not reach bedrock. These terraces occur only along the major streams of the county and are in few places more than a mile wide. (See pl. 4.)

Along Raccoon and Brush Creeks there are small areas covered with gravel that is similar to the higher-level glacial gravel in every respect except that it contains no erratic material. This gravel is known as the Carmichaels formation. In northwestern Pennsylvania its occurrence is restricted to valleys whose streams did not carry water from the melting ice sheets.

Driller's log of Valley Ice Co., well (304), Beaver Falls.

	Feet
Surface material	10
Sand and gravel, with some clay; small quantity of water	18
"Quicksand," fine; very little water	43
"Mud seam," gray	1
Fine sand and gravel, gray	3
Coarse sand and pea-size gravel; large quantity of water	17
	92

The bottom of the well is finished with 15 feet of copper screen with No. 60 perforations. The water is reported to have cleared up in 35 minutes, pumping 1,000 gallons a minute. When completed, the well flowed 50 gallons a minute at 1 foot above the ground level. A drawdown of 6½ feet was produced when pumping 600 gallons a minute and a drawdown of 18 feet when pumping 1,000 gallons a minute. The present pumping rate is 400 gallons a minute, and at times this rate is maintained continuously for 48 hours.

Log of well 334

	Feet
Slag fill (1916)	34.5
Muck	2.9
Loam and sand	12.6
Sand and yellow clay	6.0
Sand, gravel, and clay	5.0
Sand and gravel	3.0
Sand, gravel, and clay	3.0
Sand and gravel, with trace of clay	12.6
Sand, gravel, and clay	2.4
	82.0

The bottom of the strainer rests on a yellow sandstone. The well is gravel-packed and yields 1,000 gallons a minute with large drawdown.

The gravel of the glacial drift yields large quantities of water to properly constructed wells. The water generally contains considerable dissolved mineral matter and is rather hard.

ROCK FORMATIONS[56]

The rocks exposed in Beaver County range from 50 feet or so above the Pittsburgh coal down to and including about 200 feet of the Pottsville formation. Only three small areas of the Pittsburgh coal and the overlying shaly sandstone beds are present in the county. These occur in the southern corner of Hopewell Township near Gringo and have an areal distribution of about one-sixteenth of a square mile.

South of a line drawn from Ambridge through New Sheffield to Hookstown none of the streams have cut their valleys deep enough to expose the top of the Allegheny formation. North of this line the upper members and still farther to the north the lower members of the Allegheny formation make their appearance in the valley bottoms, until in the vicinity of New Brighton the Allegheny formation is completely cut through and the underlying Pottsville formation exposed. In this county the Pottsville is exposed only along the Beaver River in a rather narrow band less than a mile wide and along Connoquenessing Creek in a still narrower band.

With the few exceptions noted above, the surface rocks of Beaver County belong to either the Allegheny or the Conemaugh formation. The Conemaugh has the greater areal extent, though along the north county line only the higher knobs are capped by rocks of this formation.

In general, the rocks of this county are exceedingly variable, both in thickness and in character of material. There are, however, a few members which, if used with care, make good horizon markers. These are the beds of limestone, coal, and sandstone, of which the limestone is by far the most reliable.

The following generalized stratigraphic section shows the rocks exposed in the Beaver quadrange:[57]

[56] The stratigraphy and structure of Beaver County as given here are taken mainly from L. H. Woolsey (U.S. Geol. Survey Geol. Atlas, Beaver folio (no. 134), 1905); M. J. Munn (U.S. Geol. Survey Geol. Atlas, Sewickley folio (no. 176), 1911); and F. W. DeWolf (New Castle quadrangle: Top. and Geol. Atlas of Pennsylvania, no. 5, 1929).

[57] Woolsey, L. H., op. cit., p. 16.

Generalized section for the Beaver quadrangle

Age	Formation	Thickness (feet)	Character and water-bearing properties
Pennsylvanian	Monongahela formation.	335+	Sandstone and shale overlying a coal seam of excellent quality where thickly covered. Areal distribution too small to make it of use as a source of ground water.
	Conemaugh formation.	520±	Shale and coarse sandstone with local thin beds of limestone and coal. The upper portion is prevailingly sandy; the lower part contains mostly shale. Some prominent beds of green and red shale give a distinct color to the soil on their outcrop. Sandstone members, where massive, yield good supplies of moderately mineralized water, commonly high in iron.
	Allegheny formation.	280–345	Shale, sandstone, fire clay, coal, and limestone. Sandstone predominates but in places becomes thin-bedded and shaly. Limestones, usually thin, locally develop considerable thickness. Fire clay is generally present and of great value, particularly beneath the several coal seams. Sandstone members, where thick-bedded, yield good supplies of moderately mineralized water, commonly high in iron.
	Pottsville formation.	200±	Coarse siliceous sandstone and fine conglomerate. In places massive and cross-bedded, with intermediate shale carrying iron ore and coal. Very good supplies can be obtained from sandstone members where massive. Water is somewhat mineralized and usually high in iron.

Monongahela formation. In the area south of Beaver County the Pittsburgh coal, which lies at or just above the base of the formation, is a very prominent key bed, but because of the small extent of occurrence it is not noteworthy in this county.

Conemaugh formation. The Conemaugh formation is conformable with the overlying Monongahela formation. In Beaver County the Conemaugh has an average thickness of about 520 feet and consists mainly of gray or green shale. In some localities two massive sandstone beds are present which have a decided effect on the topography. Coal and limestone, though present, are of minor thickness.

About 125 feet below the Pittsburgh coal is the top of the Morgantown sandstone member. The sandstone has an average thickness of about 65 feet and is one of the most persistent sandstones in the county. In parts of Hanover Township it thickens to as much as 100 feet. Its occurrence is restricted to the southern part of the county, where it has a decided influence on the topography. It ranges from a soft massive sandstone to a thin-bedded rock and in places seems to consist entirely of sandy shale.

Between the Morgantown sandstone and the Ames limestone lies as much as 50 feet of deep-red and yellow shale, within which occur one or more coal beds of local extent. In places the Morgantown sandstone appears to lie close to the Ames limestone, if not in direct contact with it, the intervening shale and coal being essentially absent.

The Ames limestone, by far the most persistent member of the Conemaugh formation, has certain peculiar characteristics that make it rather easy to recognize. Because of these peculiarities and its persistency, it is the best key bed in the Conemaugh. It lies from 230 to 265 feet below the Pittsburgh coal and from 270 to 300 feet above the Upper Freeport coal. The area over which it crops out is restricted to that portion of the county which lies south of a line drawn along

the westward-flowing stretch of the Ohio River. It is a dark-blue to greenish-gray rock with granular texture and has the appearance of a sandstone rather than of a limestone. The weathered faces present a characteristic rough surface owing to the presence of large numbers of fossils, mainly crinoid stems. This feature, together with its color, has given rise to the name "Green crinoidal limestone." The thickness ranges from 1 to 6 feet, with about 3 feet as an average. In places the bed seems to split into two parts with a separating interval as great as 35 feet.

A short distance below the Ames limestone occur beds of shale from 15 to 35 feet thick which weather to a deep blood-red soil and are therefore very conspicuous from considerable distances. These beds of shale aid greatly in locating the overlying limestone, and the two together form an excellent key horizon.

From the Ames limestone to the Mahoning sandstone there is an average of about 175 feet of reddish and greenish sandy shale and thin-bedded sandstone. Some limestone and coal also occur in this interval.

The Mahoning sandstone is usually a yellow to brown coarse-grained massive rock. In places it contains white quartz pebbles about the size of a pea. The upper part of the sandstone usually grades into shale up to the Brush Creek coal. In the eastern part of the county the member consists of two massive sandstone beds separated by shale in which limestone, coal, and clay occur locally. Either of the two massive beds may be as much as 80 feet thick, although where one is thick the other is generally thin. The combined thickness of the two sandstones, together with the intervening shale, ranges from 40 to 100 feet. In many places the Mahoning sandstone rests directly on the Upper Freeport coal, but in others they are separated by as much as 15 feet of shale, and in still others the coal and part of the underlying clay have been cut out and the basal layers of the sandstone usually contain bituminous matter.

Allegheny formation—Although there are minor unconformities between the Conemaugh and Allegheny formations, the contact over the region as a whole is one of conformity. Economically, the Allegheny is the most important formation in the county, for it contains the most valuable beds of coal, clay, limestone, and sandstone. Its total thickness ranges from 280 to 345 feet. Woolsey [58] makes the following statement regarding the irregularity of the beds of the Allegheny formation in the Beaver quadrangle.

> The individual beds vary so greatly in character and thickness throughout the quadrangle * * * that no one section can be regarded as typical of the region.

The Upper Freeport coal, the top of which marks the top of the Allegheny formation, lies about 177 feet above the Lower Kittanning coal. The Upper Freeport coal appears to have been partly or completely cut out in places by currents of water that were depositing the material that makes up the overlying Mahoning sandstone. Fragments of bituminous material and clay are incorporated in the base of the sandstone in some localities.

Between the Upper and Lower Freeport coals is an interval of 38 to 85 feet of shale and sandstone. The upper part of this interval is

[58] Woolsey, L. H., op. cit., p. 4.

prevailingly shaly and the lower part sandy. This sandy portion is the Butler sandstone, and although absent in places it attains a thickness of 40 feet in some exposures. It is a yellowish-white coarse rock, more or less lenticular in occurrence.

The Freeport sandstone occurs in the interval between the Lower Freeport coal and the Upper Kittanning coal and has a maximum thickness of 140 feet. In some places it is a massive, moderately coarse gray rock, but in others the horizon seems to be occupied entirely by shale. The base of the Freeport sandstone is very irregular. In places it is separated from the Upper Kittanning coal by shale, but in other places it cuts out all of the Upper Kittanning coal, and in the vicinity of Industry there is an exposure showing 140 feet of unbroken sandstone, the base of which begins below the horizon of the Middle Kittanning coal.

The Middle Kittanning coal lies 13 to 45 feet below the Upper Kittanning coal and 20 to 45 feet above the Lower Kittanning coal, both intervals being occupied by shale. The interval between the Lower Kittanning coal and the Vanport limestone ranges from 36 to 80 feet. The top part is more sandy than the lower part. In a few places a heavy sandstone, the Kittanning sandstone, occurs in this interval. The lower part consists mainly of dark sandy shale.

The type locality of the Vanport or Ferriferous limestone is in Beaver County in the town of Vanport, where the following section is exposed:[59]

Section of Vanport limestone at Vanport

	Ft.	In.
Blue limestone	4	..
Shale	..	4
Blue limestone	8	..
Shale	..	6
Limestone	..	6
Shale	2	2
Hard ferruginous limestone	1	..
Shale	..	6
Fossiliferous limestone	2	..
	19	..

The Vanport is irregular in thickness and where thickest is commonly divided into layers by beds of calcareous shale. It is generally gray or blue and is highly fossiliferous. The so-called "cone in cone" structure is present in many places and gives the rock a shriveled appearance. It is brittle and breaks with an irregular fracture. Iron carbonate ore a few inches thick occurs at the top of the Vanport in numerous places, though it is not so extensive as the limestone.

The Clarion coal lies 15 to 35 feet below the Vanport, the interval being occupied by clay and dark shale, though in places sandstone is present. In general, the Brookville coal is separated from the Clarion coal and clay by 50 to 60 feet of irregular shale and sandstone, and from the underlying Homewood sandstone by 5 to 10 feet of gray shale. The sandstone members of the Allegheny formation, where massive, yield good supplies of water. However, in some places the sandstones are thin-bedded or shaly and only moderate or poor supplies can be obtained.

[59] Woolsey, L. H., op. cit., p. 4.

Pottsville formation. The following is an average section of the Pottsville formation in the New Castle quadrangle:[60]

Section of Pottsville formation in New Castle quadrangle

	Range in thickness (feet)	Average thickness (feet)
Homewood sandstone	20— 60	
Shale		
Homewood coal, Four-foot, Tionesta	0— 4	40
Homewood shales with iron carbonate nodules	0— 30	
Upper Mercer limestone	0— 4	
Upper Mercer coal	0— 4½	
Upper Mercer shale	10— 25	25
Lower Mercer limestone	0— 3	
Lower Mercer coal	0— 2½	
Lower Mercer shale	5— 45	
Upper Connoquenessing sandstone	40— 84	
Shale		
Quakertown coal	0— 1¾	
Fire clay		110
Shale with iron carbonate nodules	1— 60	
Lower Connoquenessing sandstone	20—100	
Shale with iron carbonate nodules	10— 20	
Sharon coal	0— 1	
Sandy shale	20	
Concealed (Pottsville)	50	

Although less than half of the New Castle quadrangle lies in Beaver County, it is probable that the section given above represents in a general way the Pottsville formation for this county. The Connoquenessing sandstone, which in the region to the east is a single unit, is here split into two beds by the Quakertown coal, fire clay, and shale.

The top of the Homewood sandstone marks the top of the Pottsville formation. Where the horizon is marked by shaly beds, as along Connoquenessing Creek, the upper limit of the formation is rather obscure. The type locality of the Homewood sandstone is in this county, at the town of Homewood, on the Beaver River a few miles from the north county line, where a massive sandstone 155 feet thick occurs. De Wolf[61], however, is of the opinion that the 155 feet of sandstone represents the Homewood and Upper Connoquenessing combined; and that there is room for the entire Allegheny series above its top, though somewhat thinner than usual. "The reason for considering that the Connoquenessing and Homewood sandstones are united at Homewood is that the bed is unusually thick and that the additional thickness seems largely to be at the base. Furthermore, the neighboring sections lend themselves readily to such an interpretation, and in the absence of fossil evidence the facts seem to require it."

The sandstone is massive, hard, gray, yellow, or white, usually coarse and conglomeratic, and commonly cross-bedded. Because of its resistance to weathering it is a cliff maker and in a number of localities has been quarried.

The Mercer shale member occupies the interval between the Homewood and Connoquenessing sandstones. As shown in the section

[60] DeWolf, F. W., op. cit., p. 47.
[61] DeWolf, F. W., op. cit., p. 49.

given above, the member has an average thickness of about 25 feet, and although it is usually present, the individual beds are more or less irregular. The Mercer shale is exposed in this county only along the upper part of the Beaver Valley.

Records of wells drilled in Beaver County show the Pottsville formation to contain three sandstones in general. Whether the lowest one represents the Sharon conglomerate or the lower part of the Connoquenessing sandstone is not clear. Indeed, whether or not the Sharon is present at all in Beaver County is somewhat open to question, though DeWolf[62] is of the opinion that it occurs in outlying patches. Both the upper and lower sandstones of the Connoquenessing member are massive and coarse to medium grained in most localities, though in places they become thin-bedded and shaly. The average thickness of each of the two sandstones is about 40 feet. In many places they are separated by shale, coal, and clay, but in other places this shale is absent and the two sandstones are combined.

In the borough of Koppel several wells have been drilled through the lower part of the Allegheny formation into the Homewood sandstone. The records of six wells of the Koppel Water Co., show how the water-bearing properties of a rock may change in short distances. Of two wells, each 34 feet deep, one yields 6 and the other 20 gallons per minute. Two wells 47 and 48 feet deep yield 6 gallons a minute or less, and two wells 75 and 76 feet deep yield 60 gallons a minute each.

Very good supplies of moderately mineralized water can usually be obtained from the sandstone members of the Pottsville formation. However, where they are thin-bedded or shaly, smaller quantities may be expected. The water is high in iron in many localities.

The rocks below the Pottsville belong to the Pocono group, the Mauch Chunk and the upper part of the Pocono having been removed by the erosion that produced the unconformity described on page 36. The sandstone of the Pocono group will probably yield considerable water, but it will probably be salty.

Structure. As the altitude of the upland flats is about the same in the northern part of the county as in the southern part, and as the rocks that form the southern flats are about 520 feet higher in the geologic column than those that cap the northern flats, it is obvious that the strata must dip to the south. A more detailed consideration of the facts shows that the formations dip to the south-southeast about 26 feet to the mile, or about a quarter of a degree. This statement is true only in a general way, for locally there are slight reversals of dip, resulting in minor anticlines, synclines, and domes. The difference in altitude of any one stratum in adjacent synclines and anticlines is usually less than 60 feet.

GENERAL GROUND-WATER CONDITIONS

Beaver County is moderately well supplied with ground water. Small springs are rather numerous and are utilized to some extent in the rural districts. Dug wells, though not uncommon, have in most places been abandoned, the present supplies being obtained from drilled wells.

The gravel of the glacial drift and alluvium is by far the most

[62] DeWolf, F. W., op. cit., p. 60.

valuable water producer in the county. The outwash gravel occurs chiefly along the major streams. Here also is the main industrial development of the county, and it seems probable that the availability of ground water along these valleys has played no small part in determining the location of the industries.

The water-bearing properties of sand and gravel have been described on page 45. The deposits that form the higher-level terraces are usually thin and rest on bedrock shelves. In most places they lie above the water table and are therefore not noteworthy sources of water. The deposits that form the terraces nearer stream level are much thicker than the higher ones, and because they extend below the water table they can almost always be depended upon to yield large supplies of water.

Domestic needs in the areas back from the major streams are supplied, in the main, by shallow drilled wells that end in the sandstone and shale of the three lower formations of the Pennsylvanian series. Of the rock formations, sandstone beds are the largest producers, although their variability in composition makes it difficult to generalize for any one horizon. In this part of the State the depth of a bedrock well does not in general indicate the distance of the water table below the surface, but rather the distance that must be drilled before encountering permeable beds that lie below the water table.

The table on page 92 shows that the depth to water level may be either great or small, depending on the location of the well. Other things being equal, wells on steep slopes will have low water levels (well 306), whereas wells in the valley lowlands may even flow (well 304). The structure of the bedrock in this county produces artesian conditions in some regions. Wells 297, 299, 308, 337, and 338 encountered water that was under artesian pressure. Not many flowing wells are likely to be drilled in Beaver County, though some may encounter water under artesian pressure. Wells that end in glacial drift may in some localities be flowing wells. (See wells 304 and 318.)

According to the statement of a water-well driller of about 30 years' experience, there has been a progressive lowering of the water table in Beaver County. He also states that no dug wells are in use in the county, many of them having gone dry because of the lowered water table.

QUALITY OF WATER

Analyses of water collected in Beaver County are tabulated on page 54. Most of the waters analyzed came from glacial drift along the Ohio River. Water high in sodium chloride (salt water) may be expected in wells drilled into the glacial gravel in the Monaca-Rochester region. The sodium chloride is reported to come from old oil and gas wells near by that were never properly plugged. The analysis of water from well 325 shows high sodium, chloride, bicarbonate, and iron. The well passes through 135 feet of glacial sand and gravel before entering the shale that yields the highly mineralized water. Although the driller reported very little water down to a depth of 135 feet, it would have been more desirable to develop a small supply of water before entering the shale, because the present

supply is unfit for use. The analysis of the water from a small spring (no. 1000) at Morado Springs is probably exceptional as to iron content for waters from sandstones, though in general considerable iron may be expected. The temperatures of the waters recorded in the table on page 54 are fairly close to the mean annual temperature, which over a period of 14 years averaged 52.3° F.

PUBLIC SUPPLIES

The table on page 91 shows that about 45 per cent of the total quantity of water supplied by the public waterworks of Beaver County is derived from wells. Practically all of this ground water comes from the gravel deposits along the Ohio and Beaver rivers. Although new wells are being put down from time to time by the different water companies, the available supply will be adequate for some time to come, provided the wells are properly constructed and spaced.

The water of some of the municipal supplies is not pure enough to be used without chlorination. In some places the wells are near urban communities but at lower altitudes and are therefore liable to serious contamination. Moreover, most of the wells are near the river and extend below the river level. Therefore, at certain seasons of the year polluted river water may get into the wells. This subject is discussed further on page 44.

The borough of Monaca obtains its supply of water from an infiltration crib buried in the sand and gravel in the bottom of the Ohio River. Figure 10 gives the location of the crib and nearby wells with respect to the surrounding territory. The crib is about 150 feet from the river bank, and in 1898, when it was installed, it was covered with about 8 feet of sand and gravel, the gravel being about the size of a man's fist or larger. Owing to dredging operations and river scour, it is believed that there is as little as 2 feet of gravel cover in places at the present time. The crib is 150 feet long, 4½ feet deep, and about 15 feet wide. The sides are made of 2 by 10-inch oak planks spaced 2 inches apart. The roof consists of 2 by 6-inch oak planks placed edgewise with ¼-inch openings between. The bottom of the crib is open to the underlying gravel. The entire crib is divided by partitions into sections about 8 feet long. The long axis parallels the course of the Ohio River.

In order to determine whether the crib was supplying river water or ground water, samples of water for chemical analysis were taken in November 1928, from three sources—the Ohio River, the Monaca crib, and the wells at Beaver Borough, about a mile downstream (318 and 319, fig. 10).

The results of the analyses of these three waters are given on page 55 and are shown graphically in figure 11, according to the system used in representing chemical analyses by diagram described by Collins.[63]

Figure 11 shows clearly that the crib water (101) had an entirely different chemical character from that of the river water (102) and that except for the sodium chloride the crib water was similar to that of the Beaver wells (22), though somewhat lower in calcium, magnesium, sulphate, and bicarbonate. See analyses 1001, 1002, and 318.

[63] Collins, W. D., U.S. Geol. Survey Water-Supply Paper 596, pp. 256-258, 1928.

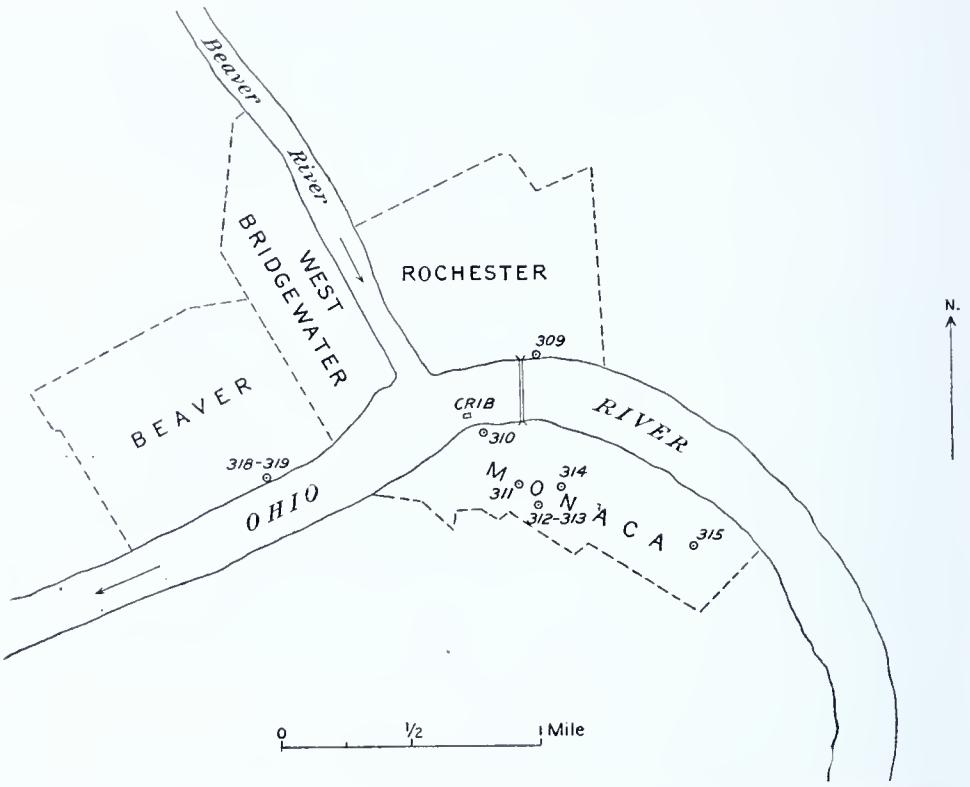


Figure 10.—Map of Monaca and vicinity, Beaver County, showing location of infiltration crib in Ohio River and near-by wells

In this vicinity gravel wells about 90 feet deep yield water that is somewhat salty, because some old oil and gas wells in the vicinity were never properly plugged and have permitted salt water to leak into the gravel.

There seemed, therefore, to be two possible interpretations of the analyses made in 1928—(1) that the crib was supplying chiefly ground water similar to that of the Beaver wells, the slightly lower calcium, magnesium, sulphate, and bicarbonate being due to a mixture of river water, and the higher sodium and chloride being due to the leaking oil and gas wells in the vicinity; or (2) that the ground water around Monaca was not only higher in sodium chloride than that from the Beaver wells but also lower in calcium, magnesium, sulphate, and bicarbonate and that the crib was supplying ground water with no admixture of river water.

To determine further the source of the crib water, samples of the water from the crib, river, and 7 near by wells were collected in July 1929. Figure 12 shows graphically the results of nine of these analyses. Two samples of river water were taken from midstream at the Monaca bridge, one at 1 p.m. July 30 (103, fig. 12) and one at 5 p.m. on the same day (108). After pumping was started 11 successive samples were taken from the crib at intervals of a quarter of a minute at first, later increasing to 2 hours. The pumping started at 1:40 p.m. Sample 104 (see fig. 12) was taken at 1:44 p.m., sample 105 at 1:55 p.m., sample 106 at 3:25 p.m., and sample 107 at 5:25 p.m. The samples from the 7 wells were collected in the morning of July 30.

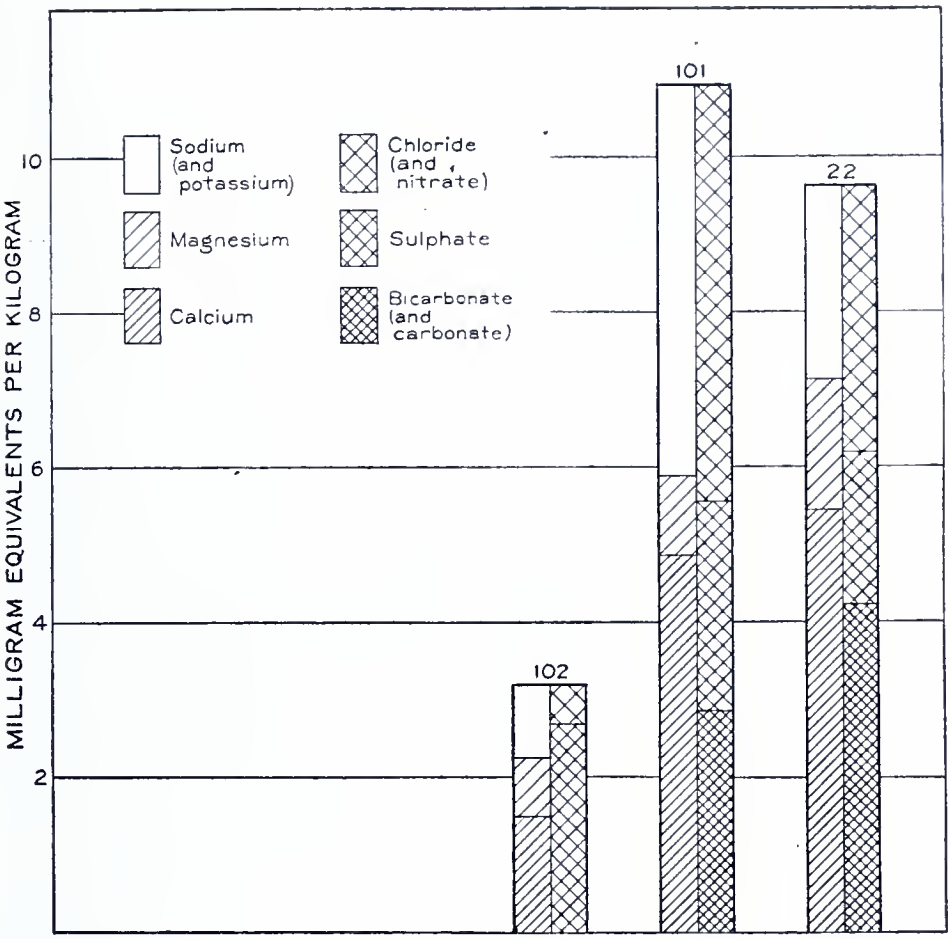


Figure 11.—Graphic representation of analyses of water from Ohio River (102), Monaca crib (101), and wells at Beaver Borough (22)

If the crib is yielding all river water or all ground water the chemical character of the water should vary but little over a short period of time. However, if the crib is supplying water consisting of a mixture of ground water and river water the chemical character of the water might vary considerably after the start of pumping, although it seems probable that after pumping at a constant rate for a time the proportions of the two should become more or less fixed and give a water of constant chemical character. Nos. 104 to 107 in figure 12 at first glance do not seem to support this view. However, there seems to be a plausible explanation of the irregular change in the character of the crib water as shown in figure 12.

The factors that determine what proportions of ground water and river water enter the crib are the relative permeabilities of the river bottom and of the water-bearing gravel, and the relative hydrostatic heads of the river and ground waters. Although no data are at hand as to the relative permeability of the river bottom and the gravel in which the crib is buried, it seems probable that the river bottom is the less permeable. Figure 10 shows that the crib is located at a point where slack-water conditions should prevail—that is, on the

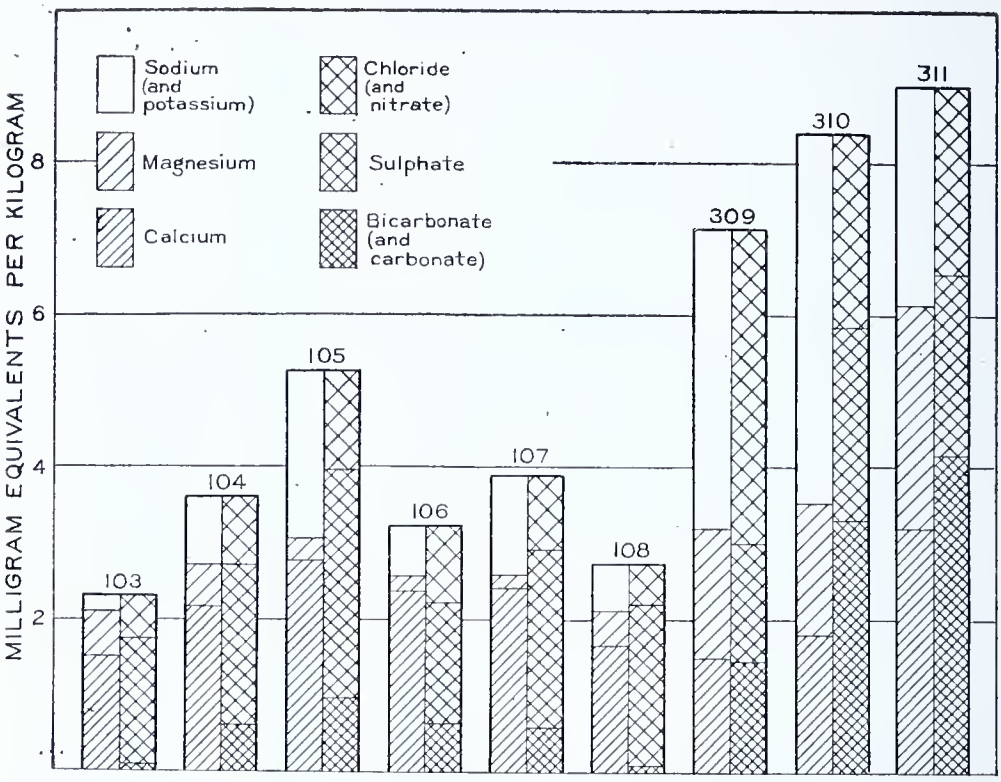


Figure 12.—Graphic representation of partial analyses of water from Ohio River, Monaca crib, and three near-by wells, Beaver County

Ohio River 103, 108; Monaca crib 104-7; Rochester 309; Monaca 310-11.

inside of a meander of the Ohio River and just above the mouth of the Beaver River. Silting up of the bottom of the Ohio should therefore be at a maximum at about the site of the crib. Although no accurate measurements were made to show the relation during the year of the river level to the ground-water level, it seems probable that, possibly except on a few days after heavy rains, the ground water in the area adjoining the river stands at a higher level than the river. Even the lowest water level reported in well 315 is above the level of the river. The water in the Beaver wells (318, 319) is reported to rise 18 inches above the level of the river. It appears, then, that both the determining factors mentioned above favor ground water entering the crib rather than river water.

When pumping from the crib started, the first water drawn would reduce the pressure on the inside, and this in turn would cause the surrounding water to move toward and into the crib. The water surrounding the crib just before pumping was started would as a rule be largely ground water, because the ground water, under greater head than the river water, would be slowly moving into the river and displacing the mixture of river and ground water that had surrounded the crib during the previous period of pumping. The downstream underflow of water through the gravel surrounding the crib would also partly flush out this gravel in the interval between pumping periods. This movement of ground water would not be rapid and in the interval between pumping periods would probably only partly flush out the crib and the gravel surrounding the crib. The first

water to enter the crib would therefore be ground water with some of the mixture of ground water and river water that had been produced by the previous pumping period. As soon as the pressure inside the crib was reduced by pumping, both river and ground water would respond to this reduced pressure and begin to move toward the crib. The mixture of ground water and river water surrounding the crib would enter the crib immediately, but no new river water would reach the crib until enough time had elapsed for the river water to move through the gravel between the top of the crib and the bed of the river. New ground water would probably reach the crib before new river water. This condition suggests an explanation of the change in chemical character toward ground water as shown by samples 104 and 105 in figure 12. As soon as new river water reached the crib the quantity of such water entering the crib would remain constant provided the rate of pumping remained the same. Sample 106, which was collected 1½ hours after sample 105, probably represents the crib water after the proportions of ground water and river water had become constant. It remains then to explain the apparent change toward ground water between samples 106 and 107. As shown in figure 12 the two river samples (103 and 108) show a perceptible change in chemical character. This change was presumably due to industrial wastes being emptied into the river upstream from the point of sampling. The table below shows the increase or decrease of each of the constituents during the period between the two river samples (103 and 108) and likewise between the two crib samples (106 and 107).

Increase or decrease of constituents, in parts per million, during period between two samples of river water and crib water at Monaca

	Total dissolved solids (calculated)	Calcium (Ca)	Sodium and potassium (calculated) (Na + K)	Bicarbonate radicle (HCO_3)
Ohio River (Samples 103 and 108)	+25	+ 2	+ 8.5	—1.2
Monaca crib (Samples 106 and 107)	+45	+ 4	+15	—4

	Sulphate radicle (turbidity) (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness (soap method)
Ohio River (Samples 103 and 108)	+20	— 1	— 0.1	0
Monaca crib (Samples 106 and 107)	+36	— 1	— 0.12	+ 1

It is apparent that the change in chemical character of the crib and river waters was of the same general nature. If the crib is drawing some river water and the composition of this water is changing in short periods of time, the composition of the crib water should also change accordingly.

A comparison of the analyses of both crib and river water made in November 1928 with those made in July 1929 shows much higher total dissolved solids during November than in July. The United States Weather Bureau records show that in this area almost twice as much rain fell during July 1929 as during November 1928. Both river and ground water especially the former, would tend to be lower in dissolved mineral matter during the wet season. It appears also from the two sets of analyses that the crib water in July 1929 had a higher percentage of river water than it did in November 1928. It seems probable that with the coming of the wet season the increase of hydrostatic head of the river water would at times be greater than the increase of head of the ground water, and this factor would tend to increase the percentage of river water entering the crib during the wet season.

Analyses of samples 103-108 are not included in the table on pages 54-55.

Public water supplies in Beaver County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (Pounds per square inch)	Treatment
Aliquippa [a] [d]	27,116	Woodlawn Water Co.	23 drilled wells	Glacial gravel	Suction	Direct [b]	1,500,000	1,500,000	90	Chlorine gas
			30 driven wells	do.	do.	do.	565,000	1,500,000	100	do.
Ambridge [d]	20,227	Municipal	16 drilled wells	do.	do.	do.	95,000±	60,000	100+	do.
Baden [d] [e]	1,924	do.	15 drilled wells	do.	do.	do.	1,000,000	1,300,000		do.
Beaver [d] [e]	5,665	do.								
Beaver Falls [c]	17,147	Beaver Valley Water Co.	Beaver and Ohio Rivers					5,800,000		Chlorine gas, lime alum, filters
Bridgewater	1,792	Beaver Valley Water Co.								
College Hill [c]		do.								
Colona [d]		Alliare Water Co.	3 drilled wells	Glacial gravel	Deep-well pumps	Direct [b]	55,500	12,500	110—	None
				do.	Suction	do.	60,000	40,000	122—	do.
Conway [d]	2,014	Municipal	10 drilled wells							
East Rochester	715	Beaver Valley Water Co.								
Eastvale	601	do.								
Fallston	665	do.								
Freedom	3,227	do.								
Koppel [d]	1,057	Koppel Water Co.	2 drilled wells	Homewood sandstone	Deep-well pumps	Direct [b]	112,000	20,000±		None
Midland	6,007	Midland Water Co.	Ohio River			do.	150,000	600,000		Chlorine gas, lime, soda ash, alum, filters, sedimentation
Monaca [f]	4,641	Municipal	Crib buried in Ohio River			Gravity	500,000	350,000		Chlorine gas
New Brighton Heights	9,950	Beaver Valley Water Co.								
Patterson	639	do.								
Rochester	7,726	do.								
Smiths Ferry		William Dawson	1 spring			Gravity	25,000	3,000		None
South Helghts [d] [e]	549	Crescent Beach Water Co.	2 drilled wells	Glacial gravel	Deep-well pumps	Direct	None	7,000		
				do.	Suction	Direct [b]	300,000	400,000	80	do. Chlorine gas
West Aliquippa [a] [d]		Municipal	10 drilled wells							
West Bridgewater		Beaver Valley Water Co.								

[a] In 1928 Woodlawn Borough and Aliquippa Borough consolidated as Aliquippa Borough. Old Aliquippa Borough is now known as West Aliquippa.
[b] Excess to reservoir.
[c] In 1930 Beaver Falls Borough and College Hill Borough consolidated as Beaver Falls city.
[d] See record of wells in next table.
[e] See analysis in foregoing table.
[f] See description of this supply on page 85.

Drilled wells in Beaver County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[c]	Remarks
297	4 miles southwest of Darlington	Watt	Valley	860	60	4¼	60				12	D	Water enters at contact of gravel on sandstone at 60 feet.
298	1½ miles southwest of Darlington	Francis Coal & Clay Co.	Valley wall	900	50	4¼			Middle part of Allegheny		30	Ind	Gravel and clay 20 feet, "slate" 22 feet, coal 1 foot, fire clay 7 feet.
299	1½ miles southeast of Darlington	Higher	Top of hill	1,100	52	4¼	52	Coal (?)	Lower Freeport		44	D	Gravel 32 feet, shale 4 feet, sandstone 10 feet, coal 6 feet, fire clay.
300	Koppel	Koppel Water Co.	Rock terrace	920	76	8		Sandstone	Homewood		33	P S	Yields 60 gallons a minute.
301	do.	do.	do.	920	72	8		do.	do.		33	do.	
302	1 mile east of Koppel	Mike Tuba	do.	920	71	4¼	40±	do.	do.		40	D	Gravel and clay 30 feet, sandstone 30 feet, "slate" 8 feet, coal ½ foot, fire clay 2½ feet.
303	1½ miles northwest of Beaver Falls	William Holton	Divide	1,200	48(?)	4¼		Coal (?)	Upper Freeport		26(?)	do.	
304	Beaver Falls[b]	Valley Ice Co.	Valley		92	12	75	Gravel	Glacial drift	90	flows	Ind	See log in text.
305	1 mile northwest of Beaver	J. M. Barrett	Divide	1,160	65	5⅝		Sandstone	Conemaugh formation	10	2	D	10 feet to bedrock.
306	Northwest of Beaver Borough limits	Dr. Scroggs	River bluff	1,020	300	5⅝		Black shale	Upper part of Allegheny	30	270	do.	
307	do.	Charles Eckart	do.	1,020	65	5⅝		Sandstone	Mahoning	10	25	do.	Clay and loam 10 feet, sandstone 55 feet.
308	North of Rochester Borough limits	Rochester Bridge Works	Terrace	920	105.5	8	105	do.	Allegheny formation	27.5	45	Ind	
309	Rochester	Polar Water Co.	Valley	680	40±			Gravel	Alluvium	40±		do.	6 similar wells; each well tested 75 gallons a minute. See analysis.

310	Monaca	Charles Sowash	Terrace	720	86	4½		do. (?)	Glacial drift (?)			D	See analysis.
311	do.	Josepb Runzo	do.	720	85	4½		do. (?)	do (?)		75	do.	Small drawdown. See analysis.
312	do.	Phoenix Glass Co. well 1	do.	740	115	8		do.	do.	115		Ind	Pumps about 200 gallons a minute. See analysis.
313	do.	well 3	do.	740	98			do.	do.	98		do.	Pumps about 50 gallons a minute. See analysis.
314	do.	M. K. Fronko	do.	720	96	4½		do. (?)	do. (?)			D	Small drawdown. See analysis.
315	½ mile southeast of Monaca	U.S. Sanitary Manufacturing Co.	do.	720	110	4		do.	do.	110	50	Ind	Small drawdown; yields 36 gallons a minute. See analysis, 3 other wells in use, about 80 feet deep in gravel, which yield 32, 28 and 34 gallons a minute.
316	Colona	Colonial Steel Mills	do.	760	135			do.	do.	135	80±	do.	Well does not reach bedrock.
317	do.	Allaire Water Co.	do.	760	110			do.	do.	106	78	P S Ind	3 wells 100± feet apart; 110 feet to bedrock.
318	Beaver	Beaver Borough	do.	680	20	6		do.	do.	20		P S	10 wells; river mud and sand 6 feet, gravel 4 feet, "hardpan" 6 feet, gravel 4 feet; reported to flow at 1½ feet above surface when first drilled. See analysis.
319	do.	do.	do.	680	40	6		do.	do.	40		do.	11 wells, 6 abandoned. See analysis.
320	North of Vanport	Abe Russel	River bluff	740	97	5⅝		Shale	Clarion clay	18	67	D	Yellow clay 18 feet, limestone 18 feet, shale 61 feet.
321	1 mile southwest of Bellowsville	Beaver County Home	Terrace	780	167	8	117±	Sand and gravel	Glacial drift	167	117±	do.	Well does not reach bedrock.
322	½ mile south of Merrill	Halsteter	do.	760	135	5⅝		do.	do.	135	85±	do.	do.
323	2½ miles northeast of Industry	T. M. Flocker	Divide	1,060	54	5⅝	54	Sandstone	Lower part of Conemaugh		32	do	Yellow clay 18 feet, "slate" 36 feet.
324	2 miles northeast of Industry	A. Williams	Terrace	760	135	5⅝	100±	Gravel	Glacial drift		100	do.	Well does not reach bedrock.
325	1¾ miles northeast of Industry	John G. Hogue	do.	760	200	5⅝		Sandstone	Lower part of Allegheny		150±	do.	Much gravel and sand 135 feet, "slate" 65 feet. See analysis.
326	2 miles east of Industry	W. H. Carpenter	do.	740	125	5⅝		do.	Middle part of Allegheny	50	90	do.	Loam and clay 50 feet, sandstone 75 feet
327	East of Georgetown	Dr. Davis	do.	740	150	5⅝		Sand and gravel	Glacial drift	150	100(?)	do.	Well does not reach bedrock.
328	Conway	Conway Borough	do.	680		8		Gravel	do.			P S	10 wells; not all in use.
329	Baden (on Crow Island)	Baden Borough	do.	680	25	12		do.	do.	25	0	do.	19 wells 50 feet apart. See analysis.
									do.	20	0	do.	
330	In Baden Borough	do.	do.	680	20	8		do.					6 wells. See analysis.

Drilled wells in Beaver County—Contd.

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[c]	Remarks
331	West of West Aliquippa	----------	Valley wall	920	150	5⅝	-------	Sandstone (?)	Upper part of Allegheny ---	20	110±	D	Clay and loam 20 feet, "slate" and sandstone 130 feet.
332	West Aliquippa	Aliquippa Borough	Terrace	680	41	12	-------	Sand and gravel	Glacial drift -----	41	5(?)	P S	4 wells spaced 40 feet apart have drawdown of 25 feet pumping 1,200 gallons a minute in 15 minutes. See analysis.
333	South end of Crow Island	do.	River island	680	28(?)	8	-------	do.	do.	28(?)	------	do.	6 wells.
334	Aliquippa ------	Woodlawn Water Co.	Terrace	700	82	18	------	Sand and gravel	Glacial drift	82	48(?)	P S	Gravel-packed well; yields 1,000 gallons a minute with drawdown to 3 feet of bottom. See analysis and log.
335	do.	do.	do.	700	80±	12	-------	do.	do.	80±	48(?)	do.	10 driven wells have a drawdown of 7 feet pumping 1,320 gallons a minute for 1 hour.
336	Ambridge -----	Ambridge Borough	do.	683	30±	8	-------	Gravel	do.	30±	------	do.	38 driven wells not all in use; wells tested 400 gallons a minute when driven.
337	South Heights	Crescent Beach Water Co.	Terrace	740	97	8¼	75	Sand and gravel	do.	97	59	do.	
338	do.	do.	do.	740	124	8¼	75	do.	do.	94	59(?)	do.	Bedrock encountered at 94 feet. See analysis.

[a] Altitude taken from nearest 20-foot contour. [b] Not located on map. [c] D—Domestic; Ind.—Industrial; PS—Public Supply.

CLARION COUNTY

GENERAL FEATURES

Clarion County is bordered on the east by Jefferson County, on the south and west by Armstrong County, and on the west and north by Venango and Forest counties. It has an area of 601 square miles. Next to Forest County, Clarion County has the smallest population of the counties considered in this report. According to the United States census of 1930, the county had a population of 34,531, as compared with 36,170 in 1920. The borough of Clarion, the county seat, is the largest town in the county and had a population of 3,201 in 1930. According to the Federal census, in 1929 there were 52 manufacturing establishments in Clarion County.

The Clarion River, which flows southwestward, dividing the county approximately in half, drains most of the county. Through much of its course it is a meandering stream, flowing in a narrow V-shaped valley, the walls of which rise 400 feet or more above the stream. About 2 miles below Foxburg, in the western part of the county, the Clarion joins the Allegheny River, which also flows in a narrow meandering valley, the walls of which are as much as 600 feet high in places. Redbank Creek forms the southern boundary of the county. Its northern tributaries drain much of the southern part of the county.

There are few extensive areas of flat land in the county. With the exception of a few small flat areas along some of the streams and small upland flats, the surface of the county consists of sloping ground. The highest point in the county occurs in Millcreek Township just north of the Jefferson County line, where a hilltop reaches an altitude of 1,912 feet above sea level. In the vicinity of Fryburg, in Washington Township, a number of points exceed 1,700 feet, two of which are more than 1,780 feet above sea level. Much of the county has an altitude of more than 1,400 feet. The lowest part of the county lies along the Allegheny River and has an altitude of about 840 feet. The maximum relief of the county is therefore more than 1,000 feet, although these extremes are on opposite sides of the county. However, a few miles north of St. Petersburg and about 2½ miles back from the Allegheny River rise a group of hills that are almost 800 feet higher than the river.

GEOLOGY AND GROUND WATER[64]

SURFACE DEPOSITS

The continental ice sheets that so greatly affected the surface of the region to the northwest at no place advanced into Clarion County. However, the waters produced by the melting of these great ice sheets carried outwash material down some of the streams of this county and partly filled the valleys with silt, sand, and gravel. (See pl. 4). Along the Clarion River there are deposits similar in every respect to the glacial gravel except that they contain only rocks of local derivation. Both these deposits occur in the same topographic position, and near Foxburg they are intermingled. For these reasons they are thought to be contemporaneous. Since the deposition of

[64] The stratigraphy and structure as given here are taken in the main from E. W. Shaw, E. F. Lines, and M. J. Munn, U. S. Geol. Survey, Geol. Atlas, Foxburg-Clarion folio (no. 178), 1911.

these sediments they have been greatly eroded, so that at present they cover only small areas and are therefore not noteworthy producers of water.

ROCK FORMATIONS

The rocks exposed in Clarion County extend from about 200 feet above the base of the Conemaugh formation down to and possibly through the Burgoon sandstone. More than 1,000 feet of the geologic section is therefore exposed in this county. Through its entire course across the county the Clarion River has eroded through the Pottsville formation into the underlying Burgoon sandstone. Likewise in the valley of the Allegheny River along most of its course, the valley of Redbank Creek almost as far east as New Bethlehem, Deer Creek Valley as far north as Shippenville, and a short distance up many of the smaller tributaries, the Burgoon sandstone has been cut into by the streams. The surface rocks in the two northernmost townships—Washington and Farmington—belong in the main to the Pottsville formation. Only a few of the higher knobs in the southeastern and southwestern parts of the county are composed of rocks of the Conemaugh formation. With the exceptions stated, the surface rocks of the county belong to the Allegheny formation.

Generalized section of rocks exposed in Foxburg and Clarion quadrangles[a]

Age	Formation	Thickness (feet)	Character and water-bearing properties
Pennsylvanian	Conemaugh formation,	230+	More or less sandy olive-green to gray shale with thin to thick beds of sandstone, in places conglomeratic, thin coal, and clay. Areal distribution too small for the formation to be of use as a source of water.
	Allegheny formation.	345–370	Iron-bearing shale, fine-grained to conglomeratic sandstone, limestone, and variable beds of coal and clay. Where massive, sandstone members yield moderate supplies of water of good quality, though somewhat high in iron.
	Pottsville formation.	120–130	Resistant sandstone with irregular beds of shale. Equivalent to the uppermost beds of the Pottsville in the type locality. Massive sandstone members yield good supplies of water generally high in iron.
	—— Unconformity ——		
Mississippian	Burgoon sandstone.	310	Fine more or less impure sandstone with thin to very thick lenses of shale. Where sandstone is not shaly it yields good supplies of water, generally high in iron.
	Cuyahoga formation.	35+	Hard gray shale with pebbles near top. No data available as to water in this formation, but water would probably be salty.

[a] Shaw, E. W., Lines, E. F., and Munn, M. J., op. cit., p. 18.

Conemaugh formation—Less than half of the lower part of the Conemaugh is present in Clarion County, and these rocks cap only a few of the higher knobs in the southeastern and southwestern portions of the county. Because of its small areal extent, the formation is of little value as a source of water.

Allegheny formation—Although the individual members of the Allegheny formation are variable in thickness, thinning of one seems to be accompanied by thickening of another, with the result that the formation as a whole has a rather uniform thickness, which ranges from 345 to 370 feet, the thickening taking place in a northwesterly

direction. Coarse sandstone beds are prominent in some places, although in others there appears to be no massive sandstone present. Throughout most of the formation the shales are brown, but in the central and upper portions olive-green shales are not uncommon.

The Upper Freeport or the Summit coal, the top of which marks the top of the Allegheny formation, is persistent in occurrence and lies about 245 feet above the Vanport limestone. Between the Upper and Lower Freeport coals is an interval of 30 to 50 feet occupied by sandy shales and sandstones, which in places are somewhat conglomeratic. This is the horizon of the Butler sandstone, which occurs in Armstrong County, to the south, although the name is not used in Clarion County. The Lower Freeport coal or Willcott vein lies 175 to 220 feet above the Vanport limestone. Below this coal and above the Upper Kittanning coal occurs 40 to 60 feet of the Freeport sandstone. Although this member is predominantly sandy, it may consist entirely of shale in some localities. In other localities it may be conglomeratic, with pebbles as large as 1 inch in diameter. At 130 to 180 feet above the Vanport limestone lies the horizon of the Upper Kittanning coal. The Middle Kittanning coal is 35 to 65 feet below the Upper Kittanning coal, the interval being occupied by shale and, to a lesser extent, by sandstone. The Lower Kittanning coal lies 20 to 50 feet above the Vanport limestone, the interval usually being about 35 feet. The Kittanning sandstone is a coarse, more or less massive, gray to pinkish sandstone about 50 feet thick. In the northern part of the area, where the Vanport limestone does not occur, this sandstone occupies the interval between the Lower Kittanning and Clarion coals. In places, however, sandy shale takes the place of the sandstone. Many of the upland flats in the vicinity of Knox and Clarion are formed by this sandstone.

The Vanport limestone is one of the most reliable horizon markers in northwestern Pennsylvania. To a great extent this is due to its rather unusual persistency, both in thickness and in occurrence. It is a dark-gray fossiliferous limestone averaging 7 feet in thickness in the eastern part of the area and 10 feet in the western part, where it attains a maximum thickness of 20 feet. The limestone is broken by both horizontal and vertical joints. The top of the Vanport is 110 to 130 feet above the base of the Allegheny formation and about 245 feet below the Upper Freeport coal. The general presence of a resistant chert bed about 1 foot thick near the top of the limestone makes the horizon more conspicuous. On top of the limestone is a thin layer of iron carbonate or oxide, which in the early days, when the ore was utilized in many parts of western Pennsylvania, gave the underlying limestone the name "Ferriferous." In a portion of the north-central part of the county and a small area around Foxburg the Vanport is not present, and Shaw and Munn[65] conclude that its absence is not due to erosion but rather that it was never deposited. In some localities 35 feet of drab shale and iron nodules occurs between the Vanport limestone and the Upper Clarion coal. In many places the limestone is immediately underlain by a coarse sandstone about a foot or in some places considerably more in thickness. In still other places the Vanport rests directly on the Upper Clarion coal. In most of western Pennsylvania where the Clarion coal is present

[65] Shaw, E. W., Lines, E. F., and Munn, M. J., op. cit., p. 7.

it occurs as one bed. However, it was long ago pointed out by Chance[66] that in Butler, Venango, and Clarion counties the Clarion coal is split into two benches. In Clarion County the interval between the two coals ranges from a few inches to 25 feet and in most places is occupied by dark-gray shale, though locally some sandy layers occur. The lower coal lies 40 to 70 feet above the Brookville coal and 20 to 50 feet below the Vanport limestone. In the western part of the county a coal that lies 50 to 70 feet below the Vanport limestone and 20 to 30 feet above the Brookville coal is locally developed and is probably the Craigsville coal of the region to the south. The Clarion sandstone, which is well developed in some of the adjoining counties, does not appear to be present as a recognizable unit in Clarion County, the rocks both above and below the Craigsville coal being shale. The Brookville coal is very irregular both in quality and thickness. Four shale partings are rather common, and these appear to thicken northward till in the vicinity of Shippenville the top of the coal is about 24 feet from the bottom. The coal is separated from the top of the Pottsville formation by a few feet of clay, shale, or shaly sandstone.

In the vicinity of St. Petersburg water is obtained from wells of small yield in sandstone of the Allegheny formation. (See wells 436-438.) In addition to the municipal supply there are many old dug wells in the borough, most of which have been abandoned. In addition to the municipal supply at Fryburg (See well 446) there are a number of dug wells about 30 feet deep that end at the top of the Vanport limestone. The limestone is here 5 to 6 feet thick. The municipal wells of Rimersburg (See wells 461 and 462) yield more than enough water to supply the borough; in fact, well 462 is not pumped, and well 461 supplies sufficient water to meet the needs of the town. However, owing to the high content of iron, only about half the townspeople use the water. The other half rely mostly on drilled wells 25 to 48 feet deep in the upper part of the Allegheny formation.

The sandstone members of the Allegheny formation, where massive and thick-bedded, generally yield moderate supplies of water to drilled wells. The water is usually of good quality except that it is likely to be high in iron.

Pottsville formation.—Where the Brookville coal is absent the upper limit of the Pottsville formation is not definite. The top of the formation is placed at the top of the Homewood sandstone member, but in localities where the upper part of the Homewood is not massive and the shale below the Brookville coal is sandy the contact of the Pottsville and the overlying Allegheny formation is not certain. Likewise, the lower limit of the Pottsville is not clear in many places, because both the Connoquenessing sandstone and the underlying Burgoon sandstone are massive, conglomeratic, and composed of grains of the same size and roundness. In general, however, the Pottsville seems to be slightly coarser and thicker-bedded.

The Homewood sandstone is the top member of the Pottsville formation. It is a coarse-grained massive rock with an average thickness of 40 feet. In some places the horizon seems to be occupied by shale or sandy shale. In the western part of the county the rock is generally white, loosely cemented, and cross-bedded, the last character giving the

[66] Chance, H. M., Pennsylvania Second Geol. Survey Rept. VV, pp. 49-51, 1880.

beds the appearance of being tilted. In the southern part of the county a number of flat benches are produced by the Homewood.

The Mercer shale member is not so well developed in this area as in the counties to the west, although in places it attains a thickness of more than 40 feet. In the west-central part of the county it is represented by less than 1 foot of coaly shale. In the localities where it is thicker it consists of shale with irregular beds of thin coal and clay. Generally one or more coal beds 1 to 16 inches thick are present. The coal and clay are both of little value.

The Connoquenessing sandstone is the lowest member of the Pottsville formation in Clarion County. It is a coarse, massive rock, ranging in thickness from 30 to 50 feet. Where exposed in the western part of the area it is buff to white and in places, where loosely cemented, has the appearance of granulated sugar. Its similarity to the underlying Burgoon sandstone has already been mentioned.

The following is the log of a well drilled for Sligo Borough in 1926, which penetrated the lower part of the Allegheny formation, all of the Pottsville formation, and the upper part of the Burgoon sandstone:

Log of Sligo well 2, on hilltop in eastern part of borough, well 457

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	2	2	"Slate", black	8	158
Sandstone, gray	20	22	Sandstone, gray	10	168
"Slate", black	15	37	Fire clay	3	171
Sandstone, gray	27	64	"Slate" and shale	30	201
Coal (Craigsville)	3	67	Sandstone (Connoquenessing)	20	221
Fire clay	6	73	"Slate" and sandstone	5	226
Sandstone	4	77	Burgoon:		
Coal (Brookville)	1	78	Sandstone; water at 229 and 247 feet	72	298
Fire clay	3	81	"Slate", gray	10½	308½
"Slate", black	14	95	Sandstone, white	2	310½
Sandstone (Homewood)	55	150			

The above record is probably representative of the complexity of the rocks encountered in drilling in this county, and had the well started higher in the Allegheny formation, the complexity would probably have been still greater. In addition to the municipal supply and the flowing wells mentioned below, there are a number of dug wells still in use in Sligo. (See well 459.)

In many localities the Pottsville formation consists of massive sandstone, and in these localities good supplies of water can generally be obtained from wells drilled into the formation. However, where the sandstone is thin-bedded or shaly only small quantities of water should be expected. The water is generally of fair quality, though rather high in iron.

Pocono group.—The unconformity at the base of the Pennsylvanian series has been described and it was shown that because of a long period of erosion after the deposition of the Mississippian sediments and before the deposition of the Pennsylvanian sediments the contact between the two is irregular. The evidence seems to indicate that hundreds if not thousands of feet of rock was removed by erosion from this area during this interval of time. Thus the entire Mauch Chunk

formation, as well as a portion of the upper part of the Pocono group, appear to have been eroded.

The following is the classification given by Shaw and Munn for the Mississippian strata of the Foxburg and Clarion quadrangles:

Mississippian series:
  Pocono group:
    Burgoon sandstone.
    Cuyahoga formation.
      Meadville shale member.
      Unexposed shales and sandstone.
    Hundred-foot sand (believed to be stratigraphic equivalent to Berea sandstone).

The Burgoon sandstone, known to the drillers as the "Mountain sand" or "Big Injun sand," has a thickness of 300 to 320 feet. It is gray to white, though commonly much stained by iron. The sandstone is usually coarse, but in places much gray or greenish soft shale is also present, either intermingled with the sand grains or in the form of separate lenses. In some localities cross-bedding is rather prominent. The top of the Burgoon lies about 130 feet below the horizon of the Brookville coal and about 240 feet below the Vanport limestone. In places a carbonaceous shale occurs about 15 feet below the top of the Burgoon. As already noted, the top of the Burgoon sandstone cannot be established with certainty in many localities.

In the region around Clarion the Burgoon sandstone appears to be the chief water producer. (See wells 449 and 450.) Although well 450 yields about 70 gallons a minute, the drawdown is rather large. The drilling for oil and gas in this area has shown that in most places the Burgoon contains fresh water, though somewhat highly mineralized. In East Brady several wells obtain water from what is probably the Burgoon sandstone. Some water is also obtained from the Pottsville sandstones. (See wells 464-469.) These wells, however, yield only moderate quantities of water. The wells of the Foxburg waterworks also draw on the Burgoon sandstone, but the wells are of small yield. (See wells 431-435.) Both industrial and municipal supplies are derived from the Burgoon sandstone in the region around Knox (See wells 441-444), the wells yielding moderate quantities of water.

Good supplies of water can generally be obtained from the Burgoon sandstone, although only small supplies will be obtained where the sandstone is shaly. The water may be highly mineralized, somewhat salty if encountered at considerable depths, and is generally high in iron.

From the records of many deep oil and gas wells drilled in Clarion County it is estimated that below the Burgoon sandstone the Pocono group consists of 400 to 600 feet of gray sandstone and shale. The Hundred-foot sand, which may be the equivalent of the Berea sandstone, marks the base of the Pocono. No information is available as to the water-bearing properties of the Cuyahoga formation, but probably water encountered in it would be highly mineralized and salty.

Probably at no place in the county have the streams eroded through the Burgoon sandstone, although in the bottom of the Allegheny River Valley a few miles northwest of Clarion County the Meadville shale member of the Cuyahoga formation is exposed. It consists of hard dark-gray sandy shale, near the top of which is an irregular conglomer-

atic bed containing quartz pebbles slightly larger than a pea. This stratum is thought to mark the top of the Cuyahoga formation.

Structure.—The rocks of this county, in a general way, are nearly horizontal but dip to the south about 20 to 25 feet to the mile. There are, however, many minor irregularities in this regional dip. In the southeastern part of the county this southerly dip does not prevail nor does the amount of dip remain so small. Three major folds have been mapped.[68] They trend northeast, essentially parallel to the Appalachian structure that is so prominent in the mountainous region to the southeast of the area here described.

The axis of the Fairmount syncline enters Clarion County from the south about a mile east of New Bethlehem and extends to the northeast, passing into Jefferson County a short distance north and east of Shannondale. The most steeply dipping strata in Clarion County occur along the west flank of this syncline in the vicinity of New Bethlehem, where the rocks dip southeast about 175 feet to the mile.

The axis of the Kellersburg anticline enters the county a short distance west of Climax and with a waving course passes about half a mile southeast of Frogtown and on to the northeast until it leaves the county, probably near Mill Creek. The strata on its northwest flank dip 50 to 125 feet to the mile and on its southeast flank 75 to 175 feet to the mile.

The axis of the Bradys Bend syncline enters the county near Lawsonham and extends east-northeast nearly to Rockville, where it bears more to the north and dies out northwest of Brinkerton. The rocks on its flanks have dips of 25 to 75 feet to the mile.

The preceding description of the structure is based on altitudes of the Vanport limestone. Structure maps based on altitudes of the oil sands that occur below the unconformity at the base of the Pennsylvanian show that the structure of the outcropping rock is essentially the same as that of the oil sands, though the sands seem to be somewhat more intensely folded.

GENERAL GROUND-WATER CONDITIONS

Clarion County is well supplied with water, the main problem being that of obtaining water low in iron or treating the water to remove the iron. Small springs are numerous and where favorably located are utilized for domestic supplies. Such springs, however, often fail in the dry season, and although it is the common belief among the local people that many of these springs flow a constant quantity of water the year around, measurements of yield before and after rainy days show that they respond rather rapidly to local rainfall. This condition was found in a small spring just east of the Rimersburg borough line. (See p. 42.)

Although dug wells are still in use in many parts of the county, they are gradually being replaced by drilled wells. Many of the dug wells fail to supply the required amount of water in the dry seasons because of their shallow depth. They are also undesirable because of the likelihood of contamination from surface sources.

From the table of drilled wells it is evident that sandstones are by far the largest water producers in the county. This is particularly true of the Burgoon and of the sandstone members of the Pottsville forma-

[68] Shaw, E. W., Lines, E. F., and Munn, M. J., op. cit., p. 9.

tion. The depths of the wells do not indicate the amount of drilling necessary to reach saturated rock but rather the distance below the surface at which permeable beds lie. In other words, many of the wells pass through saturated shale or dense compact sandstone before entering a rock that is sufficiently permeable to allow enough water to seep into the well to supply the required needs. The variability of both the Burgoon sandstone and the sandstones of the Pottsville and Allegheny formations has already been noted. Where a sandstone lies below the water table and is relatively coarse-grained, loosely cemented, and free from much clay or shale admixture, it will yield moderately large quantities of water. Where the pore spaces of the rock are filled with cementing material or clay particles, movement and storage of ground water are reduced and only small supplies of water can be obtained. If, however, the rock is fractured or jointed, these openings will allow free movement and considerable storage of water. Such a condition occurs in many parts of the county. The Burgoon sandstone or Mountain sand appears to be the most general water producer if the county as a whole is considered. The drillers of oil and gas wells report that the Mountain sand contains fresh water over a large portion of the county. This sandstone is usually reported to be white and coarse and in many localities to contain "crevices" or open joints along which the water moves. The term "Bluff sand" is commonly used by the drillers in referring to what they believe to be the first sandstone above the Mountain sand. It appears, however, that this name has been applied to any of the sandstone members of the Pottsville formation. Although the Homewood and Connoquenessing sandstones in some localities supply moderate quantities of water, they are impermeable enough at other places to be classed as poor sources of water. The water-bearing properties of the sandstones of the Allegheny formation are similar to those of the Pottsville formation, though probably still more irregular. The small areal extent of the Conemaugh formation makes it of little value as a source of water.

The structure of the rocks in this county is such that in many places water is under artesian pressure. In wells in such places the water will rise and stand at a higher level than the depth at which it was encountered. In some places the amount of this rise will be great enough to cause the water to flow at the surface. Several wells in the vicinity of Sligo (See well 456) are of this kind. However, they are not used to any extent because of the mineral matter in the water. (See analyses 456 and 1003.) According to local reports, this water comes from the Burgoon sandstone (Mountain sand) at a depth of 100 to 150 feet. The measured yield of three of these wells was 250, 50, and 4 gallons a minute. Other flowing wells are located a few miles southeast of Clarion. (See well 451.) All these flowing wells occur in synclines. Although no wells were recorded along the Bradys Bend and Fairmount synclines, these areas probably contain artesian water.

QUALITY OF WATER

Analyses of waters from Clarion County are tabulated on a preceding page. Most of these waters are from sandstone, and many of them are high in iron. The treatment of water for the removal of iron is the main problem of most of the users of ground water in Clarion County. Methods for the removal of iron from water are described on a preceding page. In the vicinity of Sligo the Burgoon sandstone yields

water moderately high in sodium chloride. (See analyses 456, 457, and 1003.) The same sandstone is reported to yield salt water in the St. Petersburg area. In the region around Foxburg the Burgoon sandstone is reported to yield water high in iron at a depth of about 20 feet below another bed which carries water that is low in iron. The water from the upper bed contains very little dissolved mineral matter of any kind. (See analysis 431.) The water high in iron is said to be present in greater quantities than the more desirable water above. In the area around Clarion the Burgoon sandstone in general contains considerable water, but it is usually hard and carries considerable iron and hydrogen sulphide. Much of the ground water in the Clarion region has been spoiled for ordinary use by the fairly widespread practice of draining water from coal mines into the ground. According to one driller, all the potable ground waters of the area have been ruined by being mixed with mine waters high in iron. This practice should be discouraged, because it eventually will contaminate all the available supply of potable ground water over a considerable area.

PUBLIC SUPPLIES

The following table gives the data pertaining to the public water supplies in Clarion County. With the exception of New Bethlehem, all these towns depend on ground water. Sandstones are the chief water producers for municipal as well as for domestic and industrial supplies. There appears to be an abundance of water to supply the demands for some time to come. However, all the towns that depend on water from wells are using water too high in iron to be classed as desirable. Clarion is the only borough in the county that treats the water for removal of iron. All but two of the towns use ground water that is of sufficient purity for the Department of Health to require no treatment.

Public water supplies in Clarion County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Clarion [a b]	3,201	Clarion Water Co.	10 drilled wells	Burgoon sandstone	Deep-well pumps	Gravity	500,000	188,088	55	Alum, lime chlorine gas.
Catfish		Eagle Coal Co.	Springs							None.
East Brady [a]	1,563	Municipal	1 spring; 2 drilled wells (auxiliary)		Deep-well pumps	Direct[c]	10,000	15,000±		None.
Foxburg [a b]	472	Foxburg Waterworks Co.	5 drilled wells	do.	do.	Gravity	169,000	18,800	45	Hypochlorite of lime.
Fryburg [a b]		Fryburg Water Co.	1 drilled well	Connoquenessing sandstone	Deep-well pump	do.	168,000	56,000		do.
Knox [a b]	1,037	do.	2 drilled wells	Burgoon sandstone	do.	do.	135,000	43,000	60	None.
New Bethlehem	1,590	Citizens Water Co. of New Bethlehem	Redbank Creek			Gravity	30,000			Alum, soda ash, chloride of lime, sedimentation, filter.
Rimersburg [a b]	1,319	Municipal	2 drilled wells	Vanport (?) limestone; Homewood sandstone	Deep-well pumps	Direct[a]	115,000	19,500	45±	None.
St. Petersburg [a b]	487	do.	1 spring; 3 drilled wells	Sandstones in lower to middle part of Allegheny formation	do.	Gravity	126,000	15,000	75—	do.
Shippenville [a b]	473	do.	1 drilled well	Connoquenessing sandstone	Deep-well pump	do.	48,000	5,000	30	do.
Sligo [a b]	750	do.	2 drilled wells	Burgoon sandstone	do.	do.	29,000	50,000	50	do.

[a] See analysis.
[b] See record of wells in following table.
[c] Excess to reservoir.

Drilled wells in Clarion County

Map No.	Location	Owner	Topographic position	Altitude (feet)[a]	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Yield (gallons a minute)	Use of water[m]	Remarks
430	2½ miles southeast of Parkers Landing (?)[b]	W. P. Parker	Valley				75	Sandstone	Burgoon					Gas well; fresh water at 75 feet.
431	½ mile northeast of Foxburg	Foxburg Waterworks Co., well 1	Near hilltop	1,160	150	8		do.	do.		Low	10.5	P S	See analysis. Wells 431–435 spaced 150 feet apart in a semicircle.
432	do.	Foxburg Waterworks Co., well 2	do.	1,160	150	8		do.	do.		do.	9.4	do.	
433	do.	Foxburg Waterworks Co., well 3	do.	1,160	150	8		do.	do		do.	12.7	do.	
434	do.	Foxburg Waterworks Co., well 4	do.	1,160	150	8		do.	do.		do.	6.4	do.	
435	do.	Foxburg Waterworks Co., well 5	do.	1,160	170±	8		do.	do.		do.		do.	This well held in reserve; the last 20 feet encountered strong iron water.
436	1 mile north of St. Petersburg	St. Petersburg Borough well 1	Hillside	1,500	150±	6¼		do.	Kittanning			4±	do.	
437	do.	St. Petersburg Borough well 2	do.	1,500	150±	6¼		do.	do.			6	do.	200 feet north of well 436. See analysis.
438	North borough line of St. Petersburg	St. Petersburg Borough well 3	do.	1,460	160	6¼		do.	Near base of Allegheny			20	do.	See analysis.
439	5 miles northeast of Emlenton[b]	Thomas McKee					50				30	10		Oil well; fresh water at 40 and 50 feet; main supply at 50 feet.
440	do.(?),[b]	C. R. McGinis					30					10		Gas well; fresh water at 30 feet.
441	Knox	Knox Borough, well 2	Hilltop	1,540	417	5⅝		Sandstone	Burgoon		225±	30	P S	See analysis.
442	do.	Knox Borough, well 1	do.	1,540	375±	5⅝		do.	do.			24	do.	See analysis, p. 55. This well used only part of the time.

Drilled wells in Clarion County—Contd.

Map No.	Location	Owner	Topographic position	Altitude (feet)[a]	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Yield (gallons a minute)	Use of water[m]	Remarks
443	Knox	Knox Beverage & Ice Co.	Valley	1,360	160	6¼	152	Sandstone	Burgoon	26	50±	7.9	Ind	See analysis.
444	do.	Knox Glass Bottle Co.	do.	1,360	156	4½	-------	do.	do.	15	20	25.7	do.	do.
445	Shippenville	Shippenville Borough	Hilltop	1,400	255	6¼	248	do.	Connoquenessing	203	65	10	P S	See analysis. When drilled tested 35 gallons a minute for 10 hours with small drawdown.
446	Fryburg	Fryburg Water Co.	Near hilltop	1,700	208	5⅝	198	do.	do.	100	------	20	do.	Surface and shale 100 feet, white sandstone 90 feet, "slate" 8 feet, sandstone 10 feet. See analysis.
447	1 mile southeast of Fryburg	United Natural Gas Co.	Valley	1,500	-------	-----	157	do.	Burgoon	------	------	------	-----	Gas well; fresh water at 157 feet.
448	1 mile southeast of Leeper	----------	do.	1,460	-------	-----	-------	----------	----------	------	Flow	------	-----	6 oil and gas wells which encountered fresh water that flowed about 20 gallons a minute from each well.
449	¾ mile northeast of Clarion	Clarion Water Co.	do.	1,100	135±	6¼	118	Sandstone	Burgoon	90	------	------	P S	10 wells spaced 100 feet apart in straight line. See analyses. Each well yields about 40 gallons a minute.
450	1 mile southeast of Clarion	Berney Brand Glass Co.	Hillside	1,460	300±	6¼	300±	do.	do.	------	------	69	Ind	Drawdown of 46 feet pumping 69 gallons a minute. Old oil well plugged at 300± feet. See analysis.
451	3 miles southeast of Clarion	----------	Valley	1,325	-------	-----	-------	do.	do.	------	------	------	-----	Old oil well; copious flow of fresh water (1907). Gas well 1 mile east along run flows salt water.[c]
452	1½ miles northeast of Reidsburg	----------	do.	1,353	2,560	-----	-------	do.	do.	------	------	------	-----	Old gas well; fresh water in Burgoon sandstone, bottom of which is at 500 feet.[d]
453	2 miles northwest of Reidsburg	----------	Hillside	1,240	1,049	-----	265±	do.	do.	------	------	------	-----	Old oil well; fresh water in hard gray sandstone from 253 to 276 feet; salt water in sandstone from 520 to 540 feet.[e]
454	1 mile north of Sligo	----------	Valley	1,145	1,075	-----	-------	do.	do.	------	------	------	-----	Old oil well; salt water in sandstone from 385 to 416 feet and from 785 to 790.[f]

455	Near Sligo on Licking Creek[h]	----------	do.	----------	-------	-----	-------	do.	do.	------	------	------	-----	Two old oil wells; salt water in one at 128, 380, and 450 feet; salt water in the other from 370 to 390 feet and from 439 to 466 feet.[g]
456	Sligo ----------	J. B. Miller ----	do.	1,120	809	-----	120	do.	do.	------	------	250	none	Old gas well; flowing 250 gallons a minute Oct. 15, 1928. See analysis.
457	do.	Sligo Borough, well 2	Hilltop --	1,280	310.5	6¼	247	do.	do.	198	210	50	P S	See analysis. Water also enters at 229 feet. See log.
458	do.	Sligo Borough, well 1	do.	1,280	313	6¼	244	do.	do.	205	210±	------	do.	This well held in reserve; 50 feet east of well 457. See analysis.
459	do.	G. W. Texter --	Valley --	1,180	14	-----	-------	Shale	Brookville elay ---	------	------	------	D	Dug well 4 feet in diameter. See record of monthly measurements and analysis.
460	3½ miles southeast of Sligo	----------	Hillside -	1,310	2,541	-----	-------	Sandstone	Burgoon	------	------	------	-----	Old gas well; salt water in sandstone from 418 to 445 feet.[h]
461	¼ mile northwest of Rimershurg	Rimersburg Borough	Near valley --	1,320	476	6¼	260	do.	Homewood	171	100	36	P S	Plugged at 370 and 260 feet. See analysis.
462	do.	do.	Hillside -	1,360	310	8¼	158	Limestone (?)	Vanport -	195	55	17	do.	Plugged at 158 feet. See analysis.
463	1½ miles east of East Brady	R. M. Kiefer	Crest of ridge --	1,340	213	8	-------	Sandstone	Middle of Allegheny	------	------	------	D.	See analysis, p. 55; yields about 50 barrels a day; water level fluctuates greatly with season; well ends on Lower Kittanning coal.
464	East Brady	East Brady Waterworks Co., upper well	Hillside -	1,040	115	4¼	-------	Sandstone	Homewood	------	------	------	P S	Used only in dry season.
465	do.	East Brady Waterworks Co., lower well	do.	900	76	6⅝	-------	do.	Connoquenessing ---	------	25±	16	do.	do.
466	do.	Rex Hide Rubber Co. ----------	River terrace	840	51	5⅝	-------	do.	Burgoon member(?)	50±	38±	28	Ind	Large drawdown.
467	do.	do.	do.	840	53	5⅝	-------	do.	do.	50±	38±	25	do.	do.
468	do.	do.	do.	840	57	8	-------	do.	do.	50±	38±	20	do	do.
469	do.	Fordyce Woolen Mills	do.	860	71	5⅝	-------	do.	do.	------	------	------	do.	3 wells in use.
470	5½ miles west of New Bethlehem	----------	Valley --	1,331	2,677	-----	-------	do.	do.	------	------	------	-----	Old gas well; fresh water in sandstone from 40 to 50 feet below surface.[i]
471	1 mile west of New Bethlehem	----------	Hillside -	1,148	2,775	-----	-------	----------	Lower part of Allegheny --	530	------	------	-----	Old gas well; salt water from 457 to 500 feet.[j]

Drilled wells in Clarion County—Concluded

Map No.	Location	Owner	Topographic position	Altitude (feet)[a]	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Yield (gallons a minute)	Use of water[m]	Remarks
472	½ mile northwest of New Bethlehem	----------	Valley --	1,156	1,637	-----	-------	----------	----------	------	------	------	-----	Old gas well; salt water in sandstone from 270 to 297 feet.[k]
473	5½ miles north of New Bethlehem	----------	do.	1,491	-------	-----	189	Sandstone (?)	Connoquenessing (?)	------	------	------	-----	Old gas well 2,779 feet deep.[l]
474	1½ miles northwest of Summerville	Klamath Coal Mining Co. --	Ravine --	1,290	130	6	-------	Sandstone	Homewood (?)	20	25±	------	Ind	Ample quantity of water available.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] Pennsylvania Top. and Geol. Survey Comm., Report 3, p. 46, 1910.
[d] Idem, p. 55.
[e] Idem, p. 59.
[f] Idem, p. 61.
[g] Idem, pp. 62–63.
[h] Idem, p. 97.
[i] Idem, p. 85.
[j] Idem, p. 80.
[k] Idem, p. 79.
[l] Idem, p. 73.
[m] D—Domestic; Ind.—Industrial; PS—Public Supply.

CRAWFORD COUNTY

GENERAL FEATURES

Crawford County lies in the northwestern part of the area described in this report and is bounded on the west by the State of Ohio and on the north by Erie County, the northwesternmost county of Pennsylvania. Crawford County is the largest county in the northwestern part of the State and has an area of 1,038 square miles. According to the United States Census Bureau, the county had a population of 62,980 in 1930. Of the 20 largest towns in the area covered by this report, two are in Crawford County—Meadville with 16,698 inhabitants, and Titusville, with 8,055. All other towns had populations of less than 5,000. In 1929 there were 121 manufacturing establishments in the county.

With the exception of the northwest corner, all of Crawford County is drained by southward-flowing streams. The central part of the county is drained by French Creek and its tributaries, the eastern part by Oil Creek, the southwestern part by the Shenango River, and the northwestern part by Conneaut Creek, which flows northward into Lake Erie. Through most of their courses the major streams flow in flat-bottomed valleys that are deeply filled with glacial outwash. This is also true of many of the smaller streams. The streams in general have low gradients and meander back and forth on the flat valley bottoms. A number of lakes and numerous swamps lie along many of the flat-bottomed valleys. Conneaut Lake, the largest lake in the State, lies in the west-central part of the county.

The county has a maximum relief of about 1,040 feet. The lowest place, which is at the point where Conneaut Creek crosses the north county line, is less than 860 feet above sea level. The highest point occurs in the northeast corner of the county, where a number of hilltops are more than 1,900 feet above sea level. Many hilltops in the eastern part of the county rise to altitudes of more than 1,700 feet, but in the western part only a few rise above 1,300 feet. The land surface is moderately rough, steep slopes being rather numerous, particularly in the eastern and southern portions of the county. The hummocky morainic topography produced by the Wisconsin ice is rather prominent in many parts of the county, particularly along the deeply buried valleys. The larger features of relief, however, are the expression of bedrock hills and slopes.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

The surface of Crawford County was greatly changed by the ice sheets that advanced from the north. The Illinoian ice completely covered the county, and the Wisconsin ice covered all but a small part of the southeast corner. The glacial boundary is shown on plate 4. The ice planed off the highlands, in places gouged out those valleys that were parallel to the direction of the ice movement, and deposited drift, both in the valleys and on the uplands. The drift on the uplands is mainly till and is usually thin. The valley filling, however, is over 200 feet thick in many places, and in well 153, in the city of Meadville, 475 feet of outwash was encountered. Plate 4 shows the extent and thickness of the outwash material filling the valleys. With

one exception all the major valleys are filled with great thicknesses of outwash.

The logs of wells 97, 98, and 99, when plotted in cross section, offer a good example of a small buried valley. Figure 13 shows the relation of this cross section. Well 98 did not encounter bedrock, so that the exact depth of the bedrock at this site is not known. Boles Run flows on bedrock at a higher altitude than the bedrock in the old buried valley. Conditions of this sort probably exist in many parts of northwestern Pennsylvania within the glaciated area. Along French Creek

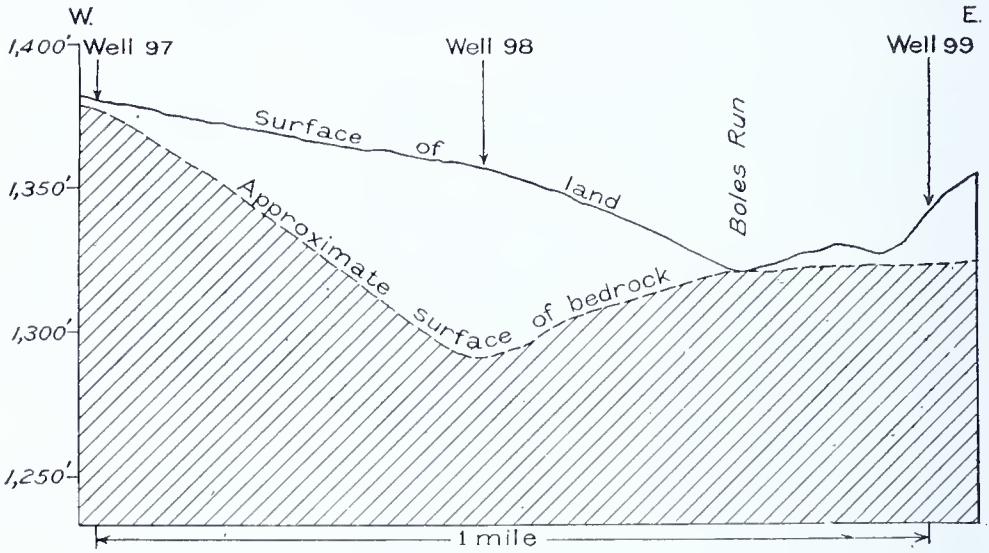


Figure 13.—Cross section showing buried valley about 4½ miles east of Crossingville, Pa.

about 2 miles south of Saegerstown the creek flows on bedrock, and the surface of the bedrock on each side of the stream stands higher than the stream. This precludes the existence of a buried valley on either side of the present stream. About a mile north of Saegerstown two wells on opposite sides of French Creek struck bedrock at depths of 15 and 16 feet.

Although about a mile to the northwest there are several wells that did not encounter bedrock at a depth of 200 feet, the altitude of the surface of the bedrock is probably great enough to eliminate the possibility of a deeply buried valley along this portion of French Creek. There appear to be no continuous deeply buried valleys along the course of French Creek between Cambridge Springs and Meadville.

In the region around Conneaut Lake there are many small springs, particularly on the east and north sides of the lake. As Conneaut Lake lies in an old buried valley, the spring water probably comes from the sand and gravel of the glacial drift.

The municipal supply of the borough of Conneautville is derived from a number of small springs about 1 mile east of the borough, in the bank of a creek. All the springs are reported to issue at the con-

tact of gravel on shale, and their combined yield is reported to be more than 50 gallons a minute.

In the town of Cambridge Springs a number of springs and wells yield "mineral water" that is reported to be of medicinal value. Some of the water is reported to be "iron water" and some of it "magnesia water." The summer population of the town of Cambridge Springs is considerably greater than the winter population because of the health resorts commercializing the supposed medicinal properties of these so-called "mineral waters."

The following is the log of a test well drilled early in 1930 for the city of Meadville:

Log of test well (152) about 1½ miles northwest of Meadville

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface	12	12	Clay, muddy, with some gravel and fine sand, about 10 per cent fine gravel	15	260
Gray mud	14	26	Clay, muddy, somewhat compact, with some gravel 1 to 2 inches in diameter	44	304
Gravel and sand, yellow	14	40	Clay, hard	12	316
Fine sand, gray	40	80	"Slate shale," gray	17	333
Fine sand and clay	10	90	"Sand shale rock"	3	336
Sand, shaly	3	93	"Slate shale" gray	7	343
Sand and clay	67	160	"Hard rock"	1	344
Clay and sand	45	205			
Sand and clay, some gravel	18	223			
Clay, muddy, with some gravel	22	245			

From this record it is not clear whether bedrock was encountered at a depth of 316 feet or at a depth of 343 feet, although the driller reports that bedrock was encountered at 343 feet. Water was first struck in this well at a depth of 26 feet, and the static water level during all drilling operations was 22 feet below the surface.

The glacial outwash sand and gravel can generally be relied upon to yield good to excellent supplies of water to drilled wells properly finished with screens. Most of the wells listed in the table of drilled wells lack screens, and many of them would undoubtedly yield larger quantities of water if properly finished. The water is usually of good quality, though somewhat hard.

ROCK FORMATIONS[69]

The rock formations exposed in Crawford County extend from the Homewood sandstone member of the Pottsville formation down to a horizon about 450 feet above the base of the Chemung formation. The rocks highest in the geologic column occur along the southern border of the county, in Greenwood, Fairfield, and Wayne townships, and the lowest occur in Spring Township, in the valley of Conneaut Creek where it leaves the county. With a few exceptions the Pottsville formation occurs only in that portion of the county which lies southeast of a line joining the southwest and northeast corners. In this area the major streams flow in valleys cut below the Pottsville, and thus the Pottsville is left only on the divides between the streams. White mapped his Venango oil sand group as occurring in bands that widen northward in the valley of Conneaut Creek from a point about a mile

[69] Taken mainly from I. C. White (Pennsylvania Second Geol. Survey Rept. Q⁴, 1881).

south of Springboro to a point about a mile south of Dicksonburg, in the valleys of Cussewago and French Creeks from the north county line to a point about a mile south of Meadville, in the valley of Woodcock Creek from Saegerstown to a point about 5 miles east of Saegerstown, and in the valley of Muddy Creek from its junction with French Creek to a point about 2 miles southeast of Little Cooley. The Venango oil sand group and the overlying Riceville shale member are correlated by Chadwick [70] with the Chagrin shale of Ohio, which contains Chemung (Upper Devonian) fossils, and the Riceville shale itself has, according to I. C. White, yielded Chemung fossils. According to Butts, [71] however, the Venango oil sand group belongs to the Conewango formation and is younger than Chemung. More work on this problem is needed. The Chemung outcrops (neglecting the cover of glacial drift) therefore extend somewhat farther south than the points described above. The remainder of the county is underlain by the Pocono group and the Conewango (?) formation.

The following generalized section of the rocks exposed in Crawford County is compiled chiefly from data given by White.

Generalized section of rocks exposed in Crawford County

Age	Formation	Thickness (feet)	Character and water-bearing properties
Pennsylvanian	Pottsville formation.	275	More or less massive conglomeratic sandstone with intervening shale, which in a few places contains limestone or coal. Area of occurrence too small for the formation to be noteworthy as a source of water.
Mississippian	Pocono group.	325±	Massive and flaggy sandstone with sandy shale and irregular limestone beds. Sandstone members, where massive, generally yield moderate supplies of water.
Mississippian or Upper Devonian	Conewango (?) formation.	65±	Sandstone, shale, and limestone. Sandstone at base may yield moderate supplies of water.
Upper Devonian	Chemung formation.	490[a]±	Flaggy sandstone and shale. Includes the Venango oil sands. Thin-bedded sandstone generally yields small supplies of water.

[a] Exposed.

Pottsville formation.—Near the southwest corner of Fairfield Township about 50 feet of the Homewood sandstone, the top member of the Pottsville formation, is present. A test hole near-by passed through 30 feet of the underlying Mercer shale member but found only a few inches of coaly material. Below the Mercer shale member is the Connoquenessing sandstone member, which in this region has a threefold division—an upper and a lower massive sandstone and an intervening bed of shale as much as 50 feet thick. The shale has been called "Quakertown shale" by I. C. White and other geologists. The two sandstones are 30 to 40 feet thick in places and are usually white. They are commonly coarse-grained and in some localities are conglomeratic. The lower sandstone in places is split into two beds, with 20 to 30 feet of intervening shale. In these localities the lower bed

[70] Chadwick, G. H., New York State Mus. Bull. 251, p. 157, 1924.
[71] Butts, Charles, U.S. Geol. Survey Geol. Atlas, Warren folio (no. 172), 1910.

forms the roof of the underlying Sharon coal. Between the Connoquenessing member and the Sharon conglomerate is the Sharon shale member, near the base of which is the Sharon coal.

The Sharon conglomerate, which is the same as the Olean conglomerate of Warren County, has a maximum thickness of about 45 feet in Crawford County. It is well exposed northeast of Meadville, where it has been extensively quarried. A rather common feature of the conglomerate is the greater percentage of coarse quartz pebbles near its base. The larger pebbles also occur near the base. In the Meadville region the largest pebbles are about the size and shape of hen's eggs, but eastward there seems to be an increase in the size of the pebbles. The member is irregular, changing in short distances from a massive conglomerate to a thin-bedded, cross-bedded sandstone. After a study of the numerous quarries in the vicinity of Meadville, Carll[72] says:

"It will be observed that irregularity of structure, variations in color, and rapid changes from conglomerate to sandstone and vice versa are conspicuously shown * * * and there can be little doubt but that similar circumstances have conspired in many places to produce similar results in all the sandy members of the Carboniferous age."

In places the rock is cemented into a hard conglomerate, but in other exposures or other parts of the same exposure the rock may be quite friable. At the College Hill quarry, northeast of Meadville, where the rock is quarried and crushed for sand, it is so friable that it can be crushed in the hand.

In parts of Crawford County water is obtained from springs or wells which is known as "mineral water" and is reported to have medicinal properties. About 2 miles southeast of Cochranton water is bottled and sold from the Mountain Top Spring. The water probably issues from the lower part of the Pottsville formation, and on June 13, 1929, the spring yielded 34 gallons a minute.

The Pottsville formation occurs only in a few small areas in the southeastern part of the county and is therefore not a noteworthy source of water. In the upland areas, where the formation is thickest, moderate supplies of water can probably be obtained from the massive sandstone members of the formation.

Pocono group.—The following generalized section of the Pocono group is compiled chiefly from data given by White:[73]

Generalized section of Pocono group in Crawford County

	Feet
Burgoon sandstone:	
Shale (Shenango shale of I. C. White)	50
Sandstone, massive (Shenango sandstone of I. C. White)	25
Cuyahoga formation (Meadville group):	
Meadville shale member:	
Upper shale	25
Upper limestone	1
Lower shale	40
Sharpsville sandstone member:	
Upper flags	50
Lower limestone	2
Lower flags	12
Orangeville shale member	100
Berea sandstone (Corry sandstone)	20
	325

[72] Carll, J. F., Pennsylvania Second Geol. Survey Rept. I³, p. 38, 1880.
[73] White, I. C., op. cit., p. 66.

The top 75 feet of sandstone and shale of the Pocono group in this area has been correlated with the Burgoon sandstone and is now called by that name. These beds are the Shenango shale and Shenango sandstone of I. C. White. The shale occurs between the Sharon conglomerate and the sandstone. It is as much as 60 feet thick, is blue, gray, or brown, and in places is somewhat sandy. Near the base of this shale an irregular layer of ironstone concretions is generally present. The sandstone, which occurs below the shale, is very widespread and persistent in this area. It is made up of moderately coarse quartz grains cemented together with iron oxide and is very resistant to weathering. It is yellowish brown to gray and commonly contains many iron concretions, some of them more than 1 foot in diameter. In places it is conglomeratic, but the pebbles are invariably flat and not round, as in the Sharon conglomerate, so that the two are easily distinguished. In thickness the lower or sandstone part of the Burgoon ranges from 15 to 35 feet in this area. The areal distribution of the sandstone is shown on plate 5, and as it lies near the top of the Pocono it occurs near the boundary between the Pocono and the Pottsville.

The Cuyahoga formation of this county was many years ago given the local name "Meadville group" by I. C. White, but "Cuyahoga" is the older name and has been applied over a wide area. The section given above shows the average thicknesses of the various units. The Meadville shale—the upper member of the Cuyahoga—is split into an upper and lower shale by a limestone that is composed of fish remains, together with sand grains and calcium carbonate. It is nowhere more than 1½ feet thick and is usually less than 6 inches. In most localities numerous flattish pebbles of shale or fine sandstone occur in the layer. The shales above and below the limestone are bluish gray and generally become more sandy near the base. The maximum thickness of the upper shale is about 30 feet, but the lower shale is about 60 feet thick in places. The Sharpsville sandstone member, which underlies the Meadville shale member, comprises about 60 feet of thin-bedded sandstone containing layers of gray shale. In the lower part of the member is a hard limestone rarely more than 2 feet thick. It is very persistent in this area and may be distinguished from the limestone in the overlying Meadville shale by the fact that it does not contain the fish remains so common in that bed. The Sharpsville sandstone usually becomes more shaly near the top and merges with the Meadville shale. The lower sandstone of the Sharpsville member is usually about 12 feet thick but is as much as 30 feet thick in places. The Orangeville shale forms the basal member of the Cuyahoga formation. It is a dark-bluish shale locally containing some sandy layers, and in some localities lenticular iron nodules are numerous. It is about 100 feet thick in most of Crawford County, although in places it is only 60 feet thick.

The basal formation of the Pocono group is the Berea sandstone. It is generally 10 to 15 feet thick, and nowhere in this area is it more than 30 feet thick. It is a yellowish-white to buff-gray compact, fine-grained sandstone, though in a few localities it contains pebbles. In both Crawford and Erie counties many quarries have been opened on this sandstone.

In the region around Sugar Lake there are many springs that probably issue from sandstone in the lower part of the Pottsville for-

mation or the upper part of the Pocono group. Ferry Spring, one of the largest in the region, was flowing about 280 gallons a minute on June 15, 1929. A number of oil wells have also been drilled in this region, in which fresh water was encountered that was under sufficient head to cause it to flow at the surface. The source of this fresh water is probably the sandstone of the Pocono group. Although no analyses of water from these flowing wells were made, the water is probably high in iron.

The massive sandstone members of the Pocono group will generally yield moderate supplies of water to drilled wells. Where encountered at greater depths the water is likely to be highly mineralized, high in iron, and somewhat salty.

Conewango (?) formation (Mississippian or Upper Devonian).—The rocks next underlying the Pocono group in this county are tentatively correlated with the Conewango formation of Warren County. They consist of the following members: Upper shales, 5 feet, limestone 2 feet, middle shales 30 feet, and sandstone 25 feet, at the base.

The shales of this formation average about 35 feet thick and are bluish gray. The limestone near the top resembles somewhat the two limestones in the Cuyahoga formation, though it contains no fossils in this area. In some localities the shale is replaced by thin-bedded sandstone, and in these places the limestone is absent. The basal sandstone is a buff, coarse, loosely cemented rock. Although appearing massive it crumbles to sand after exposure. In many places it contains flat quartz pebbles. The rock appears to become less friable when traced east of French Creek till along Oil Creek it is a very hard rock. It is 30 feet thick in places. The Conewango (?) formation is too thin to be a noteworthy source of water, although the sandstone at the base may yield moderate quantities of water in some localities.

Chemung formation.—The Chemung formation of Crawford County has the same general characteristics as the Chemung of Erie County. The description is therefore given under Erie County, because the entire formation is exposed in that county.

Structure.—The rocks of Crawford County, though appearing to be horizontal, dip in a southerly direction at the rate of about 15 to 20 feet to the mile. Irregularities in dip may occur but they are slight.

GENERAL GROUND-WATER CONDITIONS

Crawford County is well supplied with ground water, both for household use and for larger municipal and industrial uses. Small springs are numerous and are utilized in many places, although during the dry seasons many of them diminish in flow or even dry up, so that in general they are not reliable sources of supply. Most of the wells in the county are drilled wells, although dug wells are still in use in some areas, but because of the likelihood of contamination and the unreliability of the supply during dry seasons, they are gradually being abandoned and replaced by drilled wells.

By far the largest producer of ground water is the sand and gravel of the glacial drift. Most of the valleys in the county are partly filled with glacial outwash, which in general yields moderate to large

supplies of water to drilled wells. In some places, however, the character of this outwash is such that very little water can be obtained from it. To the driller this material is known as "quicksand," and not infrequently considerable trouble is encountered in drilling through it. Numerous failures are reported in attempting to sink wells in this material, and even where it was possible to put down the casing, very little water was obtained from some of the wells. It is probable that with more modern methods of finishing such wells by means of screens or strainers with openings of the proper size small quantities of water could be obtained from these "quicksand" deposits. In many places these layers of "quicksand" are interstratified with coarser sand or thin "streaks" of gravel, and if these layers of more permeable material are carefully watched for and properly screened and developed, considerable water can be obtained from wells which otherwise might be considered failures. This matter is further discussed on page 48.

The sandstones and the sandy shales of the Pocono group and the Chemung formation usually yield small to moderate supplies of water to shallow drilled wells. In places the shaly portions of these formations are minutely jointed and fractured, and wells ending in this sort of rock supply enough water for domestic use in many regions.

Although the structure of the rocks in Crawford County is relatively simple, water under artesian pressure, in some places sufficient to cause the well to flow at the surface, is encountered in the bedrock. (See wells 126, and 127.) Numerous wells that end in glacial drift encounter water that rises above the level at which it was struck, in some places flowing at the surface. In the table, wells 79, 85, 88, 94, 96, 98, 129, 143, and 162 are examples of this type. Other flowing wells will undoubtedly be drilled in the future, but the conditions that produce flowing wells in the glacial drift are so irregular that no prediction can be made as to the favorable locations.

QUALITY OF WATER

Analyses of waters from Crawford County are tabulated on preceding pages. From the analyses available there appears to be no striking differences between the waters from the bedrock and the waters from the glacial drift. Samples 96 and 103 contain large amounts of iron, but it is probable that a considerable portion of the iron is rust from the pump or casing, because both samples, when collected, were cloudy with finely divided particles of rust. In some of the other waters from glacial drift, however, moderate quantities of iron are present, and it is therefore probable that there is not the striking difference between the waters of the glacial drift and those of the bedrock in the quantity of iron in solution that is so noticeable in the counties to the south and southeast. Although no specific data are at hand regarding the depth at which salt water may be expected, it is probable that deep drilling in Crawford County would encounter waters high in sodium chloride. Salt waters are encountered at relatively shallow depths to the north, in Erie County, and at somewhat greater depths to the south and east, in Mercer and Venango counties, and because of the regional dip of the rocks toward the south and southeast salt water in Crawford County will probably be encountered at an intermediate depth.

PUBLIC SUPPLIES

As shown in the following table, all the municipal supplies in Crawford County are derived from ground water with the exception of Cambridge Springs and Conneaut Lake. Meadville and Titusville, the two largest towns in the county, derive their municipal supplies from a number of shallow drilled wells that end in glacial outwash. There appears to be an abundant supply of ground water for municipal use, for some time to come, although additional wells may have to be drilled in some places to meet the increased future needs. With the exception of Conneautville, none of the towns in the county that use ground water are required by the Department of Health to treat the water in order to make it safe for drinking.

The city of Meadville obtains its supply of water from four 12-inch wells about 80 feet deep drilled into the glacial outwash of Cussewago Creek about 1½ miles northwest of Meadville. Recently another well (151) has been put into service. The logs of four of the wells are shown in figure 14. The wells are situated almost in a straight line across the valley. Each well is finished with 22 feet of well screen, in which ⅛-inch slots are the largest.

A pumping test was made on three of these wells after the method of G. Thiem.[74] Thiem's equation is stated as follows:

$$P = \frac{q\ (\log_e a_1 - \log_e a)}{2\pi m\ (S\text{-}S_1)}$$

in which P = The coefficient of permeability = the number of gallons of water a day that is conducted laterally through each mile of the water-bearing bed under investigation (measured at right angles to the direction of flow), for each foot of thickness of the bed and for each foot per mile of hydraulic gradient.

q = rate of pumping, in gallons a day.

e = base of Naperian logarithms.

a_1 and a = respective distances of the two observation wells from the pumped well in feet.

π = 3.1416.

m = (for artesian conditions) = thickness of water-bearing bed, in feet.

S and S_1 = drawdown at the two observation wells, in feet.

In figure 14 well 150 is the pumped well and wells 147 and 148 are the two observation wells. The construction of the casing in well 149 was such that no measurements of the water level could be made. Well 150 was pumped at the rate of 1,230 gallons a minute for 4 hours and 33 minutes, with a drawdown of about 4 feet. The drawdown in wells 147 and 148 due to well 150 being pumped was 0.99 foot and 1.10 feet respectively (S_1 and S). The water level in all the wells stands above the bottom of the blue clay, which is relatively impervious, and the water in the permeable sand and gravel is therefore confined under artesian pressure.

[74] Wenzel, L. K., The Thiem method for determining permeability of water-bearing materials, U.S. Geol. Survey Water-Supply Paper 679-A (in preparation).

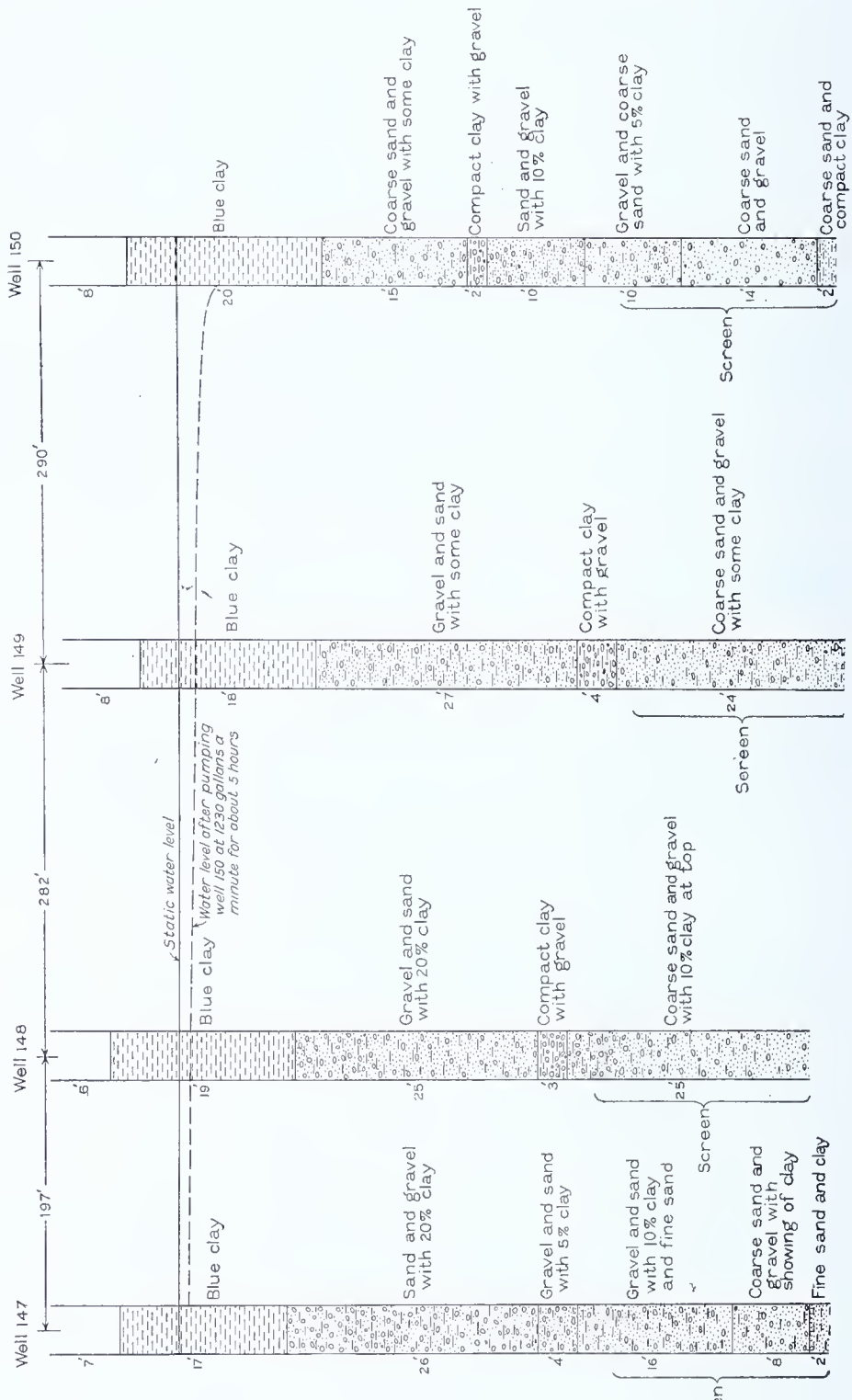


Figure 14.—Logs of four wells near Meadville, Crawford County, Pa.

On substituting in Thiem's equation the figures obtained in the test, we get the following:

$$P = \frac{1{,}771{,}200\ (6.644 - 6.349)}{2\pi 53\ (0.11)} = 14{,}264$$

In 1901 Hering & Fuller, consulting engineers for the city of Meadville, found the natural hydraulic gradient of the ground water in the Cussewago Valley to be about 6 feet to the mile, with discharge into French Creek Valley. With a hydraulic gradient of 6 feet, the width of the valley 0.7 mile, the water-bearing bed 53 feet thick, and a coefficient of permeability of 14,264, there would be a daily underflow of about 3,175,000 gallons. That is to say, that quantity of ground water is moving down the valley daily, and it is the amount that could safely be pumped from wells without withdrawing from storage. Withdrawals much greater than that amount would produce excessive and continuous lowering of water levels.

Figure 15 is the drawdown curve of an observation well about 90 feet from well 147 when wells 147, 148, 149, and 150 were being pumped at a combined rate of about 4,000 gallons a minute. At the end of 8 hours of pumping, however, the cone of depression had not reached equilibrium.

Figure 14 shows that the cone of depression is very flat, there being a 4-foot drawdown in well 150 and 0.99 foot in well 147, at a distance of 769 feet. Water-level measurements were made in well 154, about 1,250 feet upstream from wells 147-150, when those four wells were being pumped at the rate of about 4,000 gallons a minute. After 3½ hours of pumping there was a drawdown of about 2½ feet in well 154.

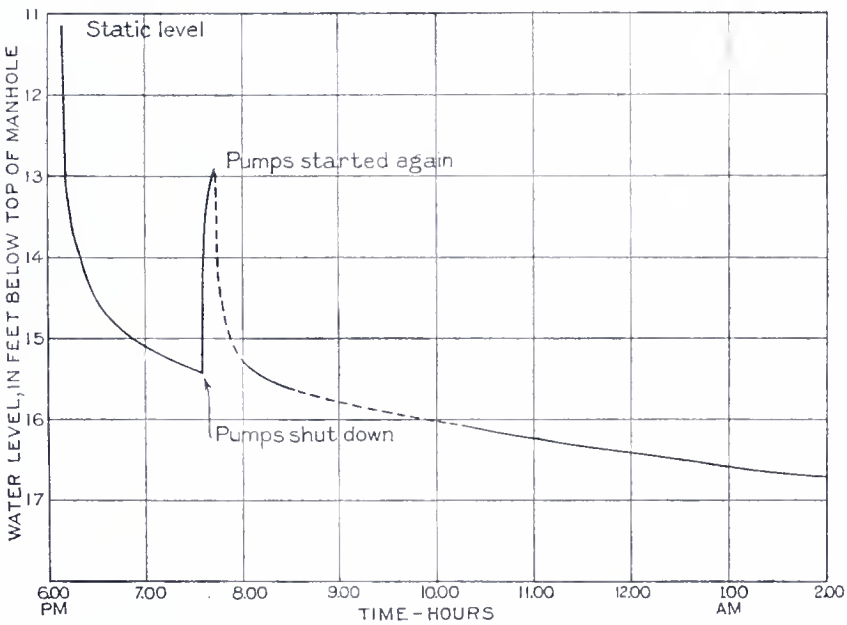


Figure 15.—Drawdown curve of observation well near well 147, when wells 147, 148, 149, and 150 were being pumped at combined rate of about 4,000 gallons a minute

Public water supplies in Crawford County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Cambridge Springs [a]	1,665	Municipal	French Creek			Direct [d]	117,000	125,000	90—	Hypochlorite of lime, alum, soda, sedimentation, filter.
Cochranton [b]	727	do.	3 springs			Gravity	233,000	50,000	103	None.
Conneaut Lake	496	do.	Conneaut Lake							Chlorine gas.
Conneaut Lake Park		From Conneaut Lake supply								
Conneautville	927	Municipal	Springs			Gravity	157,000	50,000	40	Hypochlorite of lime.
Guys Mills		Mrs. Effie Burgwin	1 spring				2,000	1,500±		
Holobar Beach		G. F. Holobar	Springs				4,200			
Linesville	963	Bunday's Water Co.	8 springs	Glacial gravel		Direct gravity [d]	200,900	61,200	75—	None.
Meadville [bc]	16,698	Municipal	5 drilled wells	do.	Turbine	Gravity	4,000,000	2,000,000	120—	do.
Saegerstown [bc]	645	do.	6 drilled wells	do.	Suction	Direct [d]	51,000	5,000	85	do.
Titusville [bc]	8,055	do.	10 drilled wells	do.	do.	Direct	None	2,250,000	80+	do.

[a] Summer population estimated at 3,500.
[b] See analysis in first part of this report.
[c] See record of wells in following table.
[d] Excess to reservoir.

Drilled wells in Crawford County

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [1]	Remarks
78	Beaver Center.	----------	Flat ----	1,030	-------	-----	-------	Shale	Upper part of Chemung ----	50	------	----	Old oil well 200 feet deep in which all fresh water was cased off at 50 feet; 3 feet to bedrock.[b]
79	Springhoro ----	L. H. Griffis --	Valley flat ---	900	113	4¼	-------	Gravel	Glacial drift -----	113	flows	D.	Well does not reach bedrock.
80	½ mile east of Conneautville	Fred Higley -----	Hillside --	1,060	74	4¼	-------	Sandstone (?)	Upper part of Chemung ----	58	30±	do.	Yellow clay and gravel 55 feet, "slate" 19 feet.
81	2½ miles northeast of Conneautville	Frank Kemitzsky	Upland flat ----	1,220	168	4¼	-------	Sandstone	do.	43	20±	do.	Small drawdown; Blue clay and gravel 40 feet, hard yellow sandstone 128 feet.
82	1 mile southeast of Conneautville	----------	Slope ----	1,060	111	-----	-------	Gravel	Glacial drift -----	111	------	do.	Well does not reach bedrock.
83	½ mile west of Conneautville	----------	Flat -----	1,020	90	-----	-------	do.	do.	90	------	do.	do.
84	do.	----------	do.	1,020	87	-----	-------	do.	do.	87	------	.do.	do.
85	2 miles west of Conneautville	John Wasko ----	Slope ----	1,100	54	4¼	53	do.	do.	54	flows	do.	Yellow clay and gravel 49 feet, hard cement gravel 4 feet, loose gravel 1 foot.
86	2½ miles west of Conneautville	----------	Valley ---	1,140	87	4¼	-------	Sandstone (?)	Upper part of Chemung ----	57	20±	do.	Yellow clay and gravel 20 feet, blue clay and gravel 15 feet, fine yellow sand 19 feet, "slate" 33 feet.
87	1½ miles north of Dicksonburg	----------	Hilltop --	1,100	126	-----	-------	Gravel	Glacial drift -----	126	------	do.	Well does not reach bedrock.
88	Dicksonburg ---	Bessemer & Lake Erie R. R. ----	Valley ---	1,000	155	4¼	-------	Sand	do.	155	flows	do.	Well does not reach bedrock; static level reported to be more than 15 feet above ground level; reported to flow 10 gallons a minute; flow on Oct. 2, 1928 was 4 gallons a minute. See analysis.

Drilled wells in Crawford County—Contd.

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [1]	Remarks
89	Dicksonburg	----------	Valley	1,020	160	-----	-------	Sand and gravel (?)	Glacial drift	160	------	D.	Well does not reach bedrock.
90	1 mile southeast of Dicksonburg	----------	Slope	1,080	102	-----	-------	Gravel	do.	102	------	do.	do.
91	1 mile west of Crossingville	Louis Hawkins	do.	1,140	54	4½	-------	Sandstone (?)	Upper part of Chemung	41	10±	do.	Blue clay and gravel 41 feet, "slate" 13 feet.
92	½ mile southwest of Crossingville	John Lucas	do.	1,120	87	4½	-------	do. (?)	do.	57	12	do.	Blue clay and gravel 57 feet, "slate" 30 feet.
93	2 miles south of Crossingville [c]	W. A. Bower	do.	---------	53	6	-------	do.	do.	13	9	do.	Bedrock encountered at 13 feet; well can be pumped dry with hand pump in 15 minutes.
94	2 miles west of Mosiertown	William Merchant	Valley flat	1,100	208	4½	195	Sand and gravel	Glacial drift	208	7±	do.	
95	8 miles southeast of Conneautville [c]	John Kepeck	----------	---------	16	-----	-------	do.	do.	-----	------	do.	Dug well 3 feet in diameter; goes dry in summer.
96	1½ miles west of Mosiertown	Vernon Schlosser	Valley flat	1,100	132	4½	128	Coarse sand	do.	132	5±	do.	"Quicksand" 128 feet, coarse black sand 4 feet. See analysis.
97	4 miles east of Crossingville	----------	Valley	1,380	87	4½	-------	Sandstone (?)	Upper part of Chemung	6	5±	do.	Yellow clay 3 feet, "slate" 84 feet.
98	4½ miles east of Crossingville	----------	Flat	1,340	57	4½	54	Gravel	Glacial drift	57	5±	do.	Yellow clay and "flagstone" 54 feet, gravel 3 feet; small drawdown.
99	5 miles east of Crossingville	----------	Slope	1,340	46	4½	-------	Sandstone (?)	Upper part of Chemung	23	10±	do.	Yellow clay 5 feet, blue clay 15 feet, "slate" 26 feet.

100	4 miles northwest of Cambridge Springs	----------	Flat -----	1,200	97	-----	-------	Gravel	Glacial drift -----	97	------	do.	Well does not reach bedrock.
101	3½ miles northwest of Cambridge Springs	----------	do.	1,180	60	-----	-------	do.	do.	60	------	do.	do.
102	2½ miles northwest of Cambridge Springs	----------	do.	1,160	110	-----	-------	do.	do.	110	------	do.	do.
103	3 miles northwest of Cambridge Springs	I. Mamrak ------	Slope ----	1,240	81	4¾	-------	do.	do.	81	17±	do.	Well does not reach bedrock. See analysis.
104	3 miles northeast of Cambridge Springs	----------	Hillside --	1,280	137	-----	-------	do.	do.	137	------	do.	Well does not reach bedrock.
105	1½ miles north of Cambridge Springs	----------	Flat -----	1,140	-------	-----	-------	----------	----------	103	------	-----	Bedrock was reached at 103 feet and below this salt water was encountered.
106	Cambridge Springs [c]	Bartlett Hotel --	Slope ----	----------	63±	6	-------	Sandstone (?)	Upper part of Chemung ----	-----	11±	D	
107	do. [c]	Bottling works -	do.	----------	80	-----	-------	do.	do.	-----	------	do.	
108	do. [c]	Crawford Hotel	do.	----------	63±	6	-------	do.	do.	40	11±	do.	
109	do. [c]	H. C. Richardson	do.	----------	63	5⅝	-------	do.	do.	-----	8	do.	
110	do. [c]	Mrs. L. R. Monroe	do.	----------	148	5⅝	-------	do.	do.	-----	------	do.	So-called "magnesia" water.
111	do. [c]	C. H. Dickinson	do.	----------	49±	5⅝	-------	do.	do.	-----	------	do.	So-called "lithia" water.
112	3 miles southwest of Lincolnville	----------	Valley ---	----------	132	-----	-------	Gravel	Glacial drift -----	132	------	do.	Well does not reach bedrock.
113	1½ miles southwest of Lincolnville	----------	----------	----------	87	-----	-------	Sand	do.	87	------	do.	Well does not reach bedrock; ends in "quicksand."
114	2 miles west of Lincolnville -	----------	----------	----------	154	-----	-------	Gravel	do.	154	------	do.	Well does not reach bedrock.
115	1 mile north of Lincolnville	----------	Lake shore --	----------	143	-----	-------	Gravel	do.	143	------	do.	do.
116	Lakeville [c] ----	----------	----------	----------	-------	-----	113	Sandstone	Upper part of Chemung ----	-----	------	-----	Old oil well 975 feet deep; water in sandstone from 113 to 114 feet.[d]
117	do. [c]	----------	----------	----------	-------	-----	142	do.	do.	-----	------	-----	Old oil well 590 feet deep; water in "crevice" at 142.[e]

Drilled wells in Crawford County—Contd.

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [b]	Remarks
118	4 miles northwest of Riceville	----------	----------	----------	200	-----	-------	Gravel	Glacial drift -----	200	------	D.	Well does not reach bedrock.
119	1 mile north of Spartansburg [c]	Ralph Elston ---	----------	-------	115±	-----	-------	Shale	----------	60	------	do.	Bedrock encountered at 66 feet.
120	Riceville -------	Church ----------	----------	----------	180	-----	-------	Gravel	Glacial drift -----	180	------	do.	Well does not reach bedrock.
121	3 miles northwest of Titusville [c]	----------	----------	----------	-------	-----	80	Shale	----------	----	------	----	Old oil well 582 feet deep; freshwater "crevice" at 80 feet; salt water in sandstone from 532 to 553 feet. [f]
122	1 mile west of Titusville	Titusville city --	Valley flat ----	1,200	65	8	-------	Gravel	Glacial drift -----	65	15±	PS	7 wells; lower 10 feet of casing perforated; these and the 3 wells under no. 123 are spaced about 40 feet apart and together they yield about 2¼ million gallons a day. See analysis.
123	do.	do.	do.	1,200	68	10	-------	do.	do.	68	15±	do.	3 wells; lower 10 feet of casing is perforated. See analysis.
124	1½ miles east of Tryonville	----------	Slope ----	1,340	150	-----	-------	do.	do.	150	------	D.	Well just reaches bedrock.
125	Townville -----	----------	Flat -----	1,410	90	-----	-------	do.	do.	90	------	do.	Well does not reach bedrock.
126	3 miles southwest of Black Ash	----------	Valley ---	1,300	-------	-----	-------	----------	----------	----	flows	none	Oil well flowing more or less mineralized water.
127	2½ miles southwest of Black Ash	----------	Slope ----	1,300	-------	-----	-------	----------	----------	-----	do.	do.	do.
128	3 miles west of Black Ash	----------	Valley flat ----	1,310	170	-----	-------	Gravel	Glacial drift -----	170	------	D.	Well does not reach bedrock.
129	1 mile northeast of Deckards [c]	----------	----------	----------	-------	-----	-------	do.	do.	-----	flows	-----	Old oil well; flows from a depth of 60 feet. [g]

130	Blooming Valley	----------	Valley flat ----	1,260	160	-----	-------	do.	do.	160	------	D.	Well does not reach bedrock.
131	2 miles southwest of Venango	----------	Hillside -------		210	-----	-------	do.	do.	210	------	do.	do.
132	3 miles northwest of Saegerstown	----------	Flat -----	1,240	96	-----	-------	do.	do.	96	------	do.	do.
133	2 miles northwest of Saegerstown	Adrel Peters ----	Slope ----	1,200	66	4½	-------	Sandstone (?)	Upper part of Chemung ----	10	6±	do.	Yellow clay and gravel 7 feet, "slate" 59 feet.
134	2 miles north of Saegerstown	----------	do.	1,280	53	-----	-------	Gravel	Glacial drift -----	53	------	do.	Well does not reach bedrock.
135	1½ miles north of Saegerstown	Bradford Luce --	do.	1,240	118	4½	-------	Sand and gravel	do.	118	88	do.	Yellow clay and cobbles 70 feet, blue clay 20 feet, yellow clay and gravel 14 feet, fine sand and small amount of gravel 4 feet.
136	2 miles north of Saegerstown	----------	do.	1,300	190	-----	-------	Gravel	do.	190	------	do.	Well does not reach bedrock.
137	do.	----------	do.	1,300	169	-----	-------	do.	do.	169	------	do.	do.
138	do.	----------	do.	1,280	166	-----	-------	do.	do.	166	------	do.	do.
139	2½ miles northeast of Saegerstown	----------	Valley ---	1,120	42	-----	-------	do.	do.	42	------	do.	do.
140	do.	----------	do.	1,120	25	-----	-	do.	do.	25	------	do.	do.
141	Saegerstown ---	Saegerstown Borough	Valley flat ----	1,100	63	6	-------	do.	do.	63	10	PS	6 similar wells; yellow clay 4 feet, gravel 59 feet. See analysis.
142	1 mile southeast of Saegerstown	----------	do.	1,100	21	-----	-------	do.	do.	21	------	D.	Well does not reach bedrock.
143	2 miles west of Saegerstown	----------	Slope ----	1,300	123	4½	110	do.	do.	123	20±	do.	Yellow clay and gravel 110 feet, black sand 13 feet.
144	Littles Corner	F. E. Oster -----	Valley flat ----	1,100	19	-----	-------	Sand	do.	-----	9	do.	Dug well 5 feet in diameter ending in "quicksand."
145	do.	----------	do.	1,100	137	-----	-------	Gravel	do.	137	------	do.	Well does not reach bedrock.
146	2 miles north of Meadville	----------	Hillside --	1,200	41	-----	-------	do.	do.	41	------	do.	do.
147	1½ miles northwest of Meadville	Meadville city well 1	Valley flat ----	1,081.3	80	12	-------	do.	do.	80	13.0	PS	See description and analysis in text.
148	1½ miles northwest of Meadville	Meadville city well 2	Valley flat ----	1,081.2	78	12	-------	Gravel	Glacial drift ----	78	12.9	PS	See description and analysis in text.
149	do.	Meadville city well 3	do.	1,080.2	81	12	-------	do.	do.	81	------	do.	do.
150	do.	Meadville city well 4	do.	1,081.5	81	12	-------	do.	do.	81	13.0	do.	do.

Drilled wells in Crawford County—Contd.

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[b]	Remarks
151	do.	Meadville city well 5	do.	1,080	94	16	-------	do.	do.	94	31.5	do.	See description in text.
152	do.	Meadville city test well	do.	1,080	344	-----	245	do.	do.	-----	22	-----	See log in text.
153	Meadville ------	Meadville Distillery Co.	do.	1,080	475	-----	-------	----------	----------	-----	------	-----	Alluvium 18 feet, gravel 27 feet, blue clay 30 feet, "quicksand" 325 feet, gravel 75 feet.[b]
154	1½ miles northwest of Meadville	Mr. Dean -------	do.	1,087	28	4¼	-------	do.	do.	28	------	D.	About 1,250 feet west of Meadville city wells.
155	do.	----------	do.	1,080	105	26	-------	do.	do.	105	16	Ind.	3-foot drawdown pumping 1,795 gallons a minute.
156	do.	----------	do.	1,080	77	26	-------	do.	do.	77	18	do.	4¾-foot drawdown pumping 2,470 gallons a minute.
157	do.	----------	do.	1,080	90	26	-------	do.	do.	90	10	do.	8-foot drawdown pumping 2,697 gallons a minute.
158	3 miles south of Meadville	----------	do.	1,080	300	-----	-------	do.	do.	300	------	-----	Well does not reach bedrock.
159	4 miles southwest of Meadville	----------	Slope ----	1,180	35	-----	-------	do.	do.	35	------	D.	do.
160	4½ miles southwest of Meadville	----------	do.	1,100	116	-----	-------	do.	do.	116	------	do.	do.
161	do.	----------	do.	1,100	50	-----	-------	do.	do.	50	------	do.	do.
162	2 miles southeast of Conneaut Lake	----------	Valley flat ----	1,080	198	-----	-------	Sand	do.	198	------	-----	Entire depth is "quicksand;" abandoned because of small quantity of water; 400 feet north of this well is a flowing well 60 feet deep in gravel.
163	2 miles east of Conneaut Lake	----------	Slope ----	1,100	50	-----	-------	Gravel	do.	50	------	D.	Well does not reach bedrock.
164	1 mile east of Conneaut Lake	----------	Flat ----	1,120	165	-----	-------	Sand	do.	165	------	-----	Well does not reach bedrock; ends in "quicksand."
165	Conneaut Lake	K. Moody -------	do.	1,100	50	-----	-------	Sandstone (?)	Pocono group ----	25	------	D.	Yellow clay and gravel 25 feet, "slate" 25 feet. See analysis.

166	2½ miles northeast of Conneaut Lake	----------	Valley ---	1,120	61	-----	-------	Gravel	Glacial drift -----	61	------	do.	Well does not reach bedrock.
167	3 miles northeast of Conneautville	United Natural Gas Co.	do.	1,180	-------	-----	-------	Shale	Lower part of Pocono (?) -------	-----	------	-----	Bedrock encountered at 80 feet.
168	1 mile northwest of Conneaut Lake	----------	Hilltop --	1,100	110	-----	-------	Gravel	Glacial drift -----	110	------	-----	Well does not reach bedrock.
169	3 miles northwest of Conneaut Lake	----------	Flat -----	1,100	97	-----	-------	do.	do.	97	------	D.	do.
170	3 miles southeast of Linesville	----------	Slope ----	1,100	93	-----	-------	do.	do.	93	------	do.	do.
171	3½ miles east of Linesville	----------	do.	1,120	46	-----	-------	do.	do.	46	------	do.	do.
172	4 miles east of Linesville	----------	Valley ---	1,100	100	-----	-------	do.	do.	100	------	do.	do.
173	3½ miles east of Linesville	----------	Flat -----	1,100	57	-----	-------	do.	do.	57	------	do.	do.
174	Hartstown -----	West Fallowfield School ----------	Hillside -	1,080	37	1½	-------	Shale	Pocono group ---	-----	22	do.	Driven well; till 10 feet, shale 27 feet.
175	3½ miles south of Hartstown	A. B. LaSalle --	do.	1,060	18	1½	-------	do.	do.	-----	------	do.	Driven well. See analysis.
176	1 mile northwest of Jamestown	----------	Hill -----	1,120	90	-----	-------	Gravel	Glacial drift -----	90	------	do.	Well does not reach bedroek.
177	½ mile northeast of Jamestown [c]	Jamestown Water Co. ----	----------	---------	122	6	-------	Sandstone	Pocono group ---	12	80	PS	Used only in dry season.
178	do.	do.	----------	---------	122	6	-------	do.	do.	12	80	do.	do.
179	do.	do.	----------	---------	120	6	-------	do.	do.	8	80	do.	do.

[a] Altitude taken from nearest 20-foot contour.
[b] Pennsylvania Second Geol. Survey Rept. Q[4], p. 212, 1881.
[c] Not located on map.
[d] Pennsylvania Second Geol. Survey Rept. I[2], p. 273, 1877.
[e] Idem, p. 274.
[f] Idem, p. 171.
[g] Pennsylvania Second Geol. Survey, Report. Q[4], p. 125, 1881.
[h] U. S. Geol. Survey Mon. 41, pp. 457-458, 1902.
[i] D—Domestic; Ind.—Industrial; PS—Public Supply.

ERIE COUNTY

GENERAL FEATURES

Erie County lies in the extreme northwest corner of the State and forms a panhandle bounded on the north by Lake Erie, on the west by Ohio, and on the east by New York. It has an area of 781 square miles. In 1930, according to the United States Census, the county had a population of 175,277. Two of the twenty largest cities in the area covered by this report are in Erie County—Erie, with 115,967, and Corry, with 7,152. The county had 419 manufacturing establishments in 1930.

The divide between the St. Lawrence River and Mississippi River drainage systems lies in Erie County roughly parallel to the shore of Lake Erie. It is nearest to the lake in the northeastern part of the county, where in a number of places it lies only about 6 miles back from the lake shore. (See plate 4). All the streams north of this divide flow into Lake Erie. They are all small streams and with two exceptions have steep gradients and flow in bedrock valleys. From a point a few miles south of Dicksonburg, in Crawford County, Conneaut Creek flows in a valley deeply filled with glacial drift until it makes a sharp bend to the west about 3 miles northwest of Albion, in Erie County, beyond which it flows on a bedrock channel. The headwaters of Crooked Creek begin near the sharp westward bend of Conneaut Creek. Crooked Creek flows in a drift-filled valley to a point about 50 feet from the lake shore, where bedrock is exposed along the edge of the stream. Southeast of the divide Erie County is drained by French Creek and its tributaries. Most of these streams flow in valleys deeply filled with glacial drift. Three small lakes occur in Erie County, all of them in drift-filled valleys. Edinboro Lake, the largest of the three, lies just north of Edinboro and has an altitude of 1,197 feet. Lake LeBoeuf is just south of Waterford and is 1,165 feet above sea level. Lake Pleasant is about 5 miles west of Wattsburg and has an altitude of 1,301 feet. Numerous small swamps occur along the divide in the eastern part of the county.

Along the shore of Lake Erie throughout most of Erie County a steep cliff as much as 170 feet high rises abruptly above the lake. This cliff is composed mainly of glacial till, though at places near its base it is made up of bedrock. The foot of the cliff at most places lies at the water's edge and is continually being cut back by wave action, which tends to maintain the steep slope of the face. From the top of this cliff for a distance of about 2 miles back from the lake the surface is a relatively flat plain that rises to the southeast. The flatness of the plain is in places broken by low ridges composed of sand and gravel. These were formed as beach ridges during the glacial epoch, when the lake stood at a higher level. About 3 to 4 miles back from the lake a rather abrupt rise in the surface produces a scarp, which in the eastern part of the county has a rise of 400 feet in 1 mile. (See fig. 6). South of this scarp the surface continues to rise gradually. Several hills along the New York State line rise more than 1,700 feet above sea level, but along the Ohio State line the highest land is less than 980 feet above sea level. The highest land in the county occurs about 3 miles south of Corry, where the hilltops are more than 1,900 feet above sea level. The altitude of Lake Erie

is 573 feet, and the maximum relief of the county is therefore more than 1,300 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

Erie County was entirely covered by ice during the glacial epoch, and many changes in the topography of the county were brought about by the action of the glaciers. Plate 4 shows the extent and thickness of outwash. Most of the valleys south of the divide are deeply filled with clay, sand, and gravel. There appears to be only one buried valley that is continuous across the divide to Lake Erie. The upper part of Conneaut Creek flows in a buried valley to a point a short distance above Albion. There the present creek makes a sharp bend to the west and enters a bedrock gorge, in which it flows for the rest of its course in Pennsylvania. The old buried valley appears to extend northward from this bend, following the present course of Crooked Creek to Lake Erie. The plain between the shore of Lake Erie and the escarpment 5 to 10 miles back from the shore is underlain by glacial drift more than 100 feet thick in some localities. The drift consists in places of clay, sand, and gravel and in other places of dense impervious till. Too few well records are available in the area occupied by this plain to show the nature of the bedrock surface, although probably the surface forms a somewhat undulating plain sloping from the escarpment toward the lake. As shown in the first part of this report, the buried valleys in the southeastern part of the county do not continue across this plain to the lake. The glacial drift on the uplands between the valleys is in most places thin and in general consists of dense impervious till.

The well of Mr. Jensen (54) 2½ miles northeast of Wattsburg has sufficient pressure to force the water to the second story of the house. The driller reports that about every 5 or 6 years the pressure decreases so much that the well has to be cleaned out, after which the pressure returns to normal. Several other flowing wells are reported in the region that derive their water from the glacial drift. There are several flowing wells on the property of the State Fish Hatchery about 2½ miles west of Corry. Some of the wells when first drilled are reported to have flowed at about 10 feet above the ground surface, but at present their head is about 2 feet above the surface. Some of these wells are reported to have flowed as much as 30 gallons a minute. The deepest well on the property (well 70) was flowing 2 gallons a minute on July 5, 1928. The following measurements of the flow of one of the 65-foot wells shows that there is considerable fluctuation in yield of these wells: July 5, 1928, 17 gallons a minute; October 11, 1928, 15 gallons a minute; July 20, 1929, 19 gallons a minute.

Springs on the Fish Hatchery property are also reported to fluctuate considerably with local precipitation. According to reports, there are small springs in the vicinity of Fairview that appear to issue from the gravel at the base of the old beach ridge. They are reported to be fairly reliable supplies for domestic use. East of Erie and between the shore of Lake Erie and the Chemung escarpment, which lies about 4 miles back from the shore of the lake, shallow dug wells are reported to be in use in some of the rural regions.

The sand and gravel of the glacial drift will generally yield good to excellent supplies of water to drilled wells that are properly finished with screens. Wells with open-end casing and no screen are likely to give considerable trouble from sand. The water will generally be of good quality, though somewhat hard.

ROCK FORMATIONS

The rocks exposed in Erie County extend from the lower part of the Burgoon sandstone down to and including about 400 feet of shale and sandstone that may be the equivalent of a part of the Portage formation. The lowest rocks are exposed in the valley of Twentymile Creek, in Northeast Township. The highest rocks occur on the hilltops in southern Concord Township, where the lower part of the Burgoon sandstone caps two or three of the highest knobs. The Berea (Corry) sandstone, the basal formation of the Pocono group, has been eroded from all of Erie County except the highlands in the southern parts of Concord, Union, and LeBoeuf townships, where it overlies the Cuyahoga formation. The Pocono is therefore present only in the southern part of these three townships. With the exception of a few isolated patches of the Conewango(?) formation (Mississippian or Upper Devonian) and the small areas of Pocono, the rest of the county is underlain by the Chemung formation and possibly part of the Portage formation. Because of the small areal distribution of the Pocono group and the Conewango (?) formation in this county the reader is referred to page 113, under the heading "Crawford County," where these rocks are described.

I. C. White divided the rocks of Erie County that are now considered to belong to the the Chemung formation into the following units in descending order:

	Feet
Riceville shale	80
Venango oil sand group	310
Chemung flags	325
Girard shale	225
	940

The Riceville shale member is a bluish-gray sandy rock and in some localities is more truly a sandstone than a shale. It contains many fossils, which White identified as Chemung forms. In this area it contains no red shale. The Venango oil sand group ranges from 250 to 350 feet in thickness in Crawford and Erie counties. The group contains three sandy phases which in the region to the southeast have been large producers of oil. The First oil sand, near the top of the group, and the Second oil sand, near the middle, are not the prominent sandstones in Erie County that they appear to be in the region to the southeast, where they have been encountered in a great number of wells. In Erie County they are merely sandy phases of the blue shale in which they occur. The Third oil sand, however, retains its massive character over most of its area of occurrence in Erie County and has been extensively quarried for building stone. A common feature of this sandstone is its division into a conglomeratic phase near the top, below which the rock is finer-grained and generally whitish or bluish gray. White describes many exposures where oil was seeping out of these sandstones, particularly the lowest one.

Generalized section of Chemung flags of White

	Feet
Shale, blue, with thin sandy layers	25
Fossil bed *(Spirifer)*	1
Sandstone, somewhat massive	15
Shale	20
Sandstone, thin-bedded	15
Sandstone and fossil beds *(Spirifer)*	12
Shale, blue	30
Fossil bed *(Spirifer)*	1
Sandstone, thin-bedded	20
Shale, blue fossiliferous	50
Sandstone, thin-bedded	20
Shale, blue	3
Sandstone, thin-bedded	17
Shale, blue, fossiliferous	10
Sandstone, thin-bedded	10
Shale Sandstone, thin-bedded	75
Limestone, impure	1
	325

The sandstones in the upper part of this group of rocks are in places massive, but the other sandy layers are thin-bedded or flaggy. Nowhere do the sandstones contain pebbles. Fossils are very abundant in the upper 175 feet but are essentially lacking in the lower portions.

The Girard shale member contains sandy layers in only a few places. Its average thickness is about 225 feet. It consists mainly of gray or bluish shale that contains no fossil shells. It apparently was mapped separately by White because of the fact that the overlying Chemung strata and the underlying Portage (?) beds are sandy, whereas the Girard is dominantly shaly.

The lowest 400 feet or so of rocks exposed in Erie County consist of layers of gray shale and thin hard sandstone that may be the equivalent of a part of the Portage formation. The sandstone layers are commonly about 1 foot thick, though in places they reach 2 feet. White reports oil and gas seeps from some of the sandy layers. About a fifth of the municipal water supply of the borough of Northeast is derived from five springs that issue from the Chemung escarpment about 2 miles southeast of the borough of Northeast. The individual flow of these springs, as measured by the superintendent of the water company on September 1, 1927, was 34,560, 9,860, 20,175, 23,040, and 16,695 gallons a day. According to the superintendent, this is probably a minimum flow of these springs, and he estimates that the average flow would be about 10 per cent greater.

Log of well ending in shale of the Chemung formation, in northern part of Corry, Pa., (74)

	Thickness (feet)	Depth (feet)
Surface soil	2	2
Gravel	20	22
"Quicksand"	80	102
Clay, blue, tough	280	382
"Hardpan," gravelly	10	392
Shale, soft, water-bearing	10	402

The shale and thin-bedded sandstone of the Chemung formation generally yields only small supplies of water, which may be somewhat highly mineralized and salty.

The rocks in Erie County appear to be horizontal, though in reality they dip southward about 15 to 20 feet to the mile. There are probably minor irregularities in this uniform dip, but they undoubtedly are slight. White [75] found only one place where there was a reversal of dip. About 2 miles south of McKean the rocks dip north for a short distance.

GENERAL GROUND-WATER CONDITIONS

Erie County is well supplied with ground water for domestic use and for the smaller municipal and industrial supplies. Here, as in other parts of northwestern Pennsylvania, small springs are numerous and are utilized in many places where they are favorably located. Many dug wells are still in use, but they are gradually being abandoned because of their unreliability in the dry season and because they are more likely to be contaminated than deeper drilled wells. In parts of the county where ample water is available the water is high in sodium chloride and the main problem in these areas is therefore that of obtaining fresh water. The sand and gravel of the glacial drift are by far the largest producers of ground water in Erie County, although in places the character of the drift is such that very little water can be obtained from it. Locally a great deal of trouble is encountered in sinking wells into the glacial drift because of caving of the softer formations into the well. Thus, many wells have been abandoned because of so-called "quicksand." It seems probable that with more modern methods of finishing wells, by the use of screens, many wells that have been abandoned as failures could be made to supply small quantities of water. The shale and particularly the sandy portions of the Chemung formation yield small quantities of water to wells in Erie County. However, large supplies should not be expected from the Chemung. In parts of Erie County water under artesian pressure is encountered in the bedrock, though in most places the pressure is not great enough to cause the well to flow at the surface. (See wells 27, 74, 75, and 76.) Owing to the irregular arrangement of the glacial drift in pockets and lenses of permeable material, many of the wells that derive their supply from the drift are flowing wells. (See wells 5, 33, 34, 35, 54, 58, 64, 65, 67, 69, 70, and 73.) Because of the irregular character of the glacial drift and the slight dip of the bedrock in Erie County, it is not possible to predict where wells should be drilled in the hope of obtaining water that will flow at the surface.

QUALITY OF WATER

Analyses of waters from Erie County are given on pages 57 and 62. Much less trouble with waters high in iron is encountered in Erie County than in the counties in the southwestern part of the area covered by this report. However, as shown in the table, some waters from glacial drift contain moderate amounts of iron. The chief problem of quality of water in Erie County is that of obtaining a supply that is low in sodium chloride. The oil- and gas-bearing rocks that lie at considerable depths further to the southeast crop out at the sur-

[75] White, I. C., The geology of Erie and Crawford Counties: Pennsylvania Second Geol. Survey Rept. Q⁴, p. 45, 1881.

face over much of Erie County and it is therefore not surprising that salt water is encountered at relatively shallow depths in this county. It is reported by one driller that along the shore of Lake Erie most of the wells are dug wells because drilled wells that encounter the bedrock usually yield salt water, which in some wells contains gas. Waters from the glacial drift are therefore more desirable than waters from the bedrock, but unfortunately in parts of Erie County the glacial drift is thin, and it is therefore not possible to obtain adequate supplies from such material. A number of relatively shallow wells which are reported to yield salt water and in some places gas are listed in the following table of drilled wells. (Wells 8, 9, 10, 11, 12, 13, 41, 42, 44, and 45). In some parts of the county, however, wells have been drilled 200 feet or so without encountering salt water. In general, wells on the higher land are likely to encounter salt water at greater depths than wells in the lower areas. According to the driller's report, in a small area northeast of Albion that extends from a point about a mile west of well 8 to well 11 (see pl. 4) more than 20 relatively shallow wells have been drilled, all of which yield water that is more or less salty. The driller reports that numerous wells outside of this small area at about the same depths yield fresh water. The analyses of water from three wells in this area (Wells 8, 9, and 10) are given in a table preceding the county descriptions. All three of these analyses show greater amounts of sodium chloride than the other analyses of waters from Erie County, although two of them, (8 and 10) are not excessively high in sodium chloride. The conditions that produce this small local area of shallow salt-water wells are not understood. However, rocks bearing oil, gas, and salt water occur in the counties to the southeast at considerable depth, and these rocks crop out in Erie County. Oil and gas seeps are not uncommon in the area along Lake Erie. This area of shallow salt-water wells may therefore be the result of some minor structural fold in the bedrock. The regional dip of the bedrock in Erie County is to the south or somewhat southeast, although in one place cited for a short distance the rocks dip slightly to the north. If this minor fold extends along the strike to the southwest it would pass through or near this small area that contains shallow salt-water wells. If this suggestion is true it is not certain whether the axis of this anticline cuts through this small area, thus bringing the rocks containing salt water near to the surface, or whether the anticlinal axis passes somewhat south of the area, thus forming a trap that prevents the free circulation of ground water. Detailed mapping of the structure of the rocks in this area will be necessary before the above suggestion can be proved to be more than mere speculation.

Wells 71 and 72 are spaced about 25 feet apart and are drawing water from the same depth. They offer an excellent example of two near by wells that yield water considerably different in concentration of dissolved mineral matter.

PUBLIC SUPPLIES

As shown in the following table all the towns in Erie County that have public water supplies with the exception of Erie and its suburbs, depend wholly or in part on ground water as their source of supply. All the towns appear to have adequate supplies of ground water for some time to come, and it appears likely that should there be a shortage additional water could be obtained by drilling more wells.

Public water supplies in Erie County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Albion [a]	1,681	Municipal	5 drilled wells, 1 dug well	Glacial gravel		Gravity	1,900,000	40,000	75±	None
Corry [a b]	7,152	Corry Water Supply Co.	28 drilled wells	do.	Suction	Direct [f]	5,000,000	1,000,000	150—	Chlorine gas
Eaglehurst		Erie municipal supply								
Edinboro [a]	789	Municipal	2 drilled wells		Deep-well pumps	Direct [f]	60,000	40,000		Hypochlorite of lime
Erie	115,967	do.	Lake Erie			do.		27,000,000		Hypochlorite of lime, alum, sedimentation, filter
Girard [a b]	1,554	do.	1 dug well	Glacial gravel	Siphon	do.	68,000	85,000	55—	None
Harbor Creek		W. S. Pole	1 drilled well				1,000			
North East [b c]	3,670	Municipal	5 springs, Sixteenmile Creek			Gravity	4,000,000	440,000	85±	Chlorine gas, alum, sedimentation, filter
Union City [d]	3,788	do.	5 springs, Bentley Run			do.	8,000,000	290,000	60	Chlorine gas
Waterford [a b]	769	Waterford Water-Supply Co.	2 drilled wells, 2 springs	Glacial gravel	Deep-well pumps	do.	100,000	50,000	60	None
Wesleyville	2,854	Erie municipal supply								
Fairview [a e]	459		2 drilled wells	Glacial gravel						

[a] See records of wells in following table.
[b] See analysis in table preceding description by counties.
[c] 20 percent ± from springs.
[d] 75 percent from springs.
[e] One well abandoned 1934 new one drilled yields 165 g.p.m. with 7-foot draw down. Depth 47 feet.
[f] Excess to reservoir.

Drilled wells in Erie County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[d]	Remarks
1	2½ miles northwest of Albion	G. Hagebone	Slope	900	103	4½		Sandstone (?)	Chemung	83	30±	D.	Yellow clay and gravel 30 feet, "quicksand" 30 feet, clay and gravel 20 feet, "slate" 23 feet.
2	1½ miles northwest of Albion	Elmer Thompson	Valley	860	113	4½		do.	do.	80	6±	do.	Blue clay and gravel 80 feet, "slate" 33 feet.
3	Albion	Bessemer & Lake Erie R.R.	Flat	910	30	3		Gravel	Glacial drift	30		do.	Well does not reach bedrock. See analysis.
4	2 miles southeast of Albion	John Zeblecabage	Hillside	1,010	51	4½		Sandstone (?)	Chemung	14	15	do.	Yellow clay and gravel 14 feet, "shell rock" 37 feet.
5	4 miles southeast of Albion	Albion Borough	Flat	1,100	29±	8		Gravel	Glacial drift	29±	flows	PS	5 similar wells; water level is about 5 feet above surface; drawdown reported to be about 15 feet. See analysis.
6	do.	do.	do.	1,100	20			do.	do.		3	do.	Dug well 10 feet in diameter. See analysis.
7	3 miles southeast of Albion		Slope	1,100	72	4½		Shale	Chemung	43	4±	D.	Sand and loam 40 feet, shale 32 feet.
8	3½ miles east of Albion	Frank R. Warner	Flat	1,120	36	4½		Sandstone (?)	do.	17	6	do.	Yellow clay and gravel 14 feet, "slate" 22 feet. See text—and analysis.
9	5 miles east of Albion	Andy Sable	do.	1,160	54	4½		Shale	do.		6±	none	Well at barn. See analysis and text.
10	do.	do.	do.	1,160	50±	4½		do.	do.			D.	Well at house. See analysis and text.
11	6½ miles northwest of Edinboro		do.	1,240	72	4½		Sandstone (?)	do.	19	16±	do.	Yellow clay and gravel 16 feet, "slate" 56 feet. See text. Water reported to be salty.
12	Platea	Charles Langdon	Slope	860	77	4½	55	Gravel	Glacial drift	77	40±	do.	Yellow clay and gravel 10 feet, blue clay 45 feet, sand and gravel 22 feet; some gas is reported coming from gravel probably from nearby improperly plugged abandoned gas well.
13	3 miles southeast of Girard		Flat	920	100	4½		Sandstone (?)	Lower part of Chemung	43		do.	Yellow clay and gravel 40 feet, "slate" 60 feet; water reported to be slightly salty.

Drilled wells in Erie County—Contd.

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[d]	Remarks
14	1½ miles northeast of Girard	Girard Borough	Slope	740	12	-----	-------	Sand and gravel	Glacial drift	-----	8	PS proposed	Dug well 20 feet in diameter; yielded by gravity about 183 gallons a minute on July 22, 1929. See analyses.
15	Fairview	J. T. Raine well 1	Flat	820	52	8	40	Gravel	do.	52	24	PS	Clay and loam 25 feet, gravel and clay 15 feet, gravel 12 feet; lower 12 feet of casing is slotted; 10-inch drawdown pumping 15 gallons a minute for 5 hours. See analysis.
16	do.	J. T. Raine well 2	do.	820	51	8	41	do.	do.	51	24	do.	Clay and loam 27 feet, gravel and clay 14 feet, gravel 10 feet, lower 10 feet of casing is slotted; 4-inch drawdown pumping 15 gallons a minute for 12 hours. See analysis.
17	2 miles northeast of McKean	-----	Valley	1,060	90	-----	-------	do.	do.	90	------	D.	Well does not reach bedrock.
18	4 miles east of McKean	-----	Slope	1,240	70	-----	-------	do.	do.	70	------	do.	do.
19	McLane	-----	Flat	1,280	98	-----	-------	do.	do.	98	------	do.	do.
20	Edinboro	-----	Valley flat	1,200	82	-----	-------	do.	do.	82	------	do.	do.
21	do.	Edinboro Borough	do.	1,200	40	-----	-------	do.	do.	40	------	PS	2 similar wells.
22	do.	-----	do.	1,200	102	-----	-------	do.	do.	102	------	D.	Well does not reach bedrock.
23	1 mile south-east of Edinboro	-----	do.	1,200	231	-----	-------	Sand	do.	231	------	-----	Well does not reach bedrock and ends in "quicksand."
24	2 miles southwest of Edinboro	-----	Hilltop	1,540	38	4¼	-------	Sandstone (?)	Lower part of Pocono	18	6±	D.	Yellow clay and gravel 10 feet, "slate" 28 feet.
25	3 miles west of Edinboro	-----	Flat	1,450	60	-----	-------	Gravel	Glacial drift	60	------	do.	Well does not reach bedrock.
26	4½ miles west of Edinboro	R. Hotchkiss	Hillside	1,260	60	4¼	-------	Sandstone (?)	Upper part of Chemung	14	15	do.	Yellow clay, gravel and "flatstone" 14 feet, "slate" and "shell" 46 feet.

27	4 miles south of Waterford	Charles Pollock	Slope	1,200	104	6	80±	Shale	do.	80	24	do.	Sand and gravel 80 feet, shale 24 feet; water also encountered at 40 feet in gravel. See analysis. Dug well nearby 20 feet deep in gravel but goes dry in dry season.
28	do.		Valley	1,160	90			Gravel	Glacial drift	90		do.	Well does not reach bedrock.
29	½ mile south of Waterford	T. B. Matchett	do.	1,180	200	4	198	do.	do.	200	14±	do.	"Quicksand" 100 feet, blue silt 98 feet, gravel 2 feet; well pumped by suction.
30	do.	Frank Ethridge	do.	1,180	201	6	180	do.	do.	201	24	do.	Soil and gravel 14 feet, quicksand 166 feet, gravel 21 feet.
31	¼ mile south of Waterford	Gas Station	do.	1,180	224			do.	do.	224		do.	Well does not reach bedrock.
32	do.	Kinnamon farm	do.	1,180						350			Old gas well in which all fresh water was shut off at 350 feet; 155 feet to bedrock.
33	Just west of Waterford	Waterford Water Supply Co. well 3	Slope	1,173	52	8	42	do.	do.	52	flows	PS	Black soil 2 feet, yellow clay 8 feet, "quicksand" 20 feet, fine gravel 12 feet, coarse gravel 12 feet; flows about 10 gallons a minute; pumps 53 gallons a minute. See analysis.
34	do.	Waterford Water Supply Co. well 1	do.	1,175	100	5⅝	97	do.	do.	100	do.	do.	Sand and gravel 15 feet, clay 18 feet, sand 2 feet, "quicksand" 30 feet, fine sand 32 feet, gravel 3 feet; drawdown 18 feet, pumping 20 gallons a minute for 14 days. See analysis.
35	do.	Waterford Water Supply Co. well 2	do.	1,173	114	5⅝	38	do.	do.	114	do.	do.	Material penetrated similar to that in well 33, below which coarse gravel interspersed with boulders was encountered; well abandoned because of small yield—10 gallons a minute.
36	Waterford	Mrs. Arthur Ensworth	Flat	1,206	243	6		do.	do.	243		D.	Material penetrated similar to that in well 37.
37	do.	Chas. Gardner	do.	1,209	242	6		do.	do.	242		do.	Top soil 5 feet, gravel 20 feet, "quicksand" 50 feet, gravel, coarse at bottom 167 feet.
38	Harborcreek	New York Central R. R.	do.	730	40	6		Shale	Portage (?)	22	20±	do.	Soil 6 feet, gravel 14 feet, shale 20 feet. See analysis.
39	2½ miles northeast of Harborcreek	J. J. Bernet	do.	780	28			Gravel	Glacial drift		24	do.	Dug well; goes dry with heavy pumping with hand pump.
40	do.	do.	do.	780	11			Sandstone (?)	Lower part of Chemung		5		Dug well 10 feet in diameter; gravel 8 feet, shale and thin-bedded sandstone 3 feet.

Drilled wells in Erie County—Contd.

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[d]	Remarks
41	3 miles west of Northeast	----------	Flat -----	750	159	5⅝	-------	Sandstone	Portage (?)	110	60	D.	Gravel and sand 105 feet, thin-bedded sandstone 54 feet; water reported as slightly salty; gas reported in well.
42	2½ miles west of Northeast	----------	do.	760	250	5⅝	-------	do.	do.	150	------	none	"Quicksand" 150 feet, thin-bedded sandstone 100 feet, some water at 20 feet in sand; water reported to be very salty; some gas reported in well.
43	3½ miles southwest of Northeast	----------	Hillside -	1,000	75	5⅝	-------	do.	Lower part of Chemung ----	20	------	D.	Gravel 20 feet, thin-bedded sandstone 55 feet.
44	Northeast -----	Ross Jones -----	Slope ---	800	128	5⅝	-------	do.	Portage (?)	14	60—	-----	Gravel 14 feet, thin-bedded sandstone 114 feet; water reported to be very salty.
45	do.[b]	----------	Flat -----	---------	99	5⅝	-------	do.	do.	30	------	D.	Gravel 30 feet, thin-bedded sandstone 69 feet; some gas reported in well; another similar well nearby is 115 feet deep.
46	2 miles north of Northeast	----------	Hillside --	640	90	5⅝	-------	do.	do.	69	60±	do.	Gravel 65 feet, thin-bedded sandstone 25 feet.
47	1½ miles east of Northeast	----------	Flat -----	840	52	5⅝	-------	do.	do.	33	15	do.	Gravel 30 feet, thin-bedded sandstone 22 feet; gas reported in well.
48	3 miles southeast of Northeast	----------	Valley --	1,240	85	5⅝	-------	do.	Lower part of Chemung ----	19	3	do.	Gravel 19 feet, thin-bedded sandstone 66 feet; another similar well nearby.
49	4 miles southeast of Northeast	----------	Slope ----	1,480	77	5⅝	-------	do.	do.	52	20	do.	Gravel 48 feet, thin-bedded sandstone 29 feet.
50	1½ miles north of Greenfield	----------	do.	1,440	104	5⅝	-------	do.	Chemung --	52	------	-----	Gravel 48 feet, thin-bedded sandstone 56 feet
51	do.	----------	do.	1,440	108	5⅝	-------	do.	do.	24	------	D.	Gravel 20 feet, thin-bedded sandstone 88 feet.

52	Lowville	Art Conrad	Valley flat	1,300	305	3				300+		do.	Shale bedrock encountered at 300 feet.
53	1 mile north of Wattsburg	T. A. Gilmore	do.	1,300	260	4					6	do.	Drawdown reported to be more than 20 feet after pumping half an hour.
54	2½ miles northeast of Wattsburg	J. L. Jensen	do.	1,340	120	4½		Gravel	Glacial drift	120	flows	do.	See text and analysis.
55	4 miles southeast of Wattsburg	Amity Township School	Slope		44			Sandstone (?)	Chemung	20	20	do.	Gravel and clay 20 feet, "slate" 24 feet.
56	2 miles northwest of Beaver Dam[b]	Garry Prebble			110			Gravel	Glacial drift	110	20±	do.	Well does not reach bedrock.
57	Beaver Dam[b]	H. Dunn	Flat		111			do.	do.	111	20	do.	Gravel 111 feet.
58	Just west of Union City[b]	Merril Soul Milk Co.			160			do.	Glacial drift (?)	110±	flows	Ind.	Clay and gravel 110 feet, shale 50 feet; numerous other gravel wells on property which flow.
59	Union City[b]	Will Gross			75			do.	do.	75	20	D.	Well does not reach bedrock.
60	do.		Flat	1,260			225				flows	none	Gas well; 100 feet to bedrock; water flowed when 225-foot depth was reached.
61	2 miles northeast of Union City[b]	Union City Borough	Slope		100	5§		Shale	Chemung	20	16±	do.	Sand and gravel 15 feet, shale 85 feet.
62	do.[b]	do.	do.		100	10		do.	do.	20	16±	do.	2 similar wells.
63	½ mile southwest of Elgin	Crawley			315			Sand	Glacial drift	315	5±	D.	"Quicksand" 310 feet, sand 5 feet.
64	Elgin[b]	Harrington			160			Gravel	do.	160	flows	do.	Well does not reach bedrock.
65	do.	Dave Lyons			250			do.	do.	250	do.	do.	do.
66	1 mile south of Concord[c]	Lilley farm					123	Sandstone (?)	Chemung				Old oil well in which large quantity of water was encountered at 123 feet; 119 feet to bedrock.
67	Lovell	Gates	Valley flat	1,380	315			Gravel	Glacial drift	315	flows	D.	"Quicksand" 314 feet, gravel 1 foot; water rises to second story of house.
68	3 miles southeast of Elgin[b]	Charles Drake			61		19	do.	do.	25	30	do.	Clay and gravel 19 feet, "slate" 42 feet.
69	2½ miles west of Corry	State Fish Hatchery	Valley	1,400	65±	4		do.	do.	65±	flows		14 similar wells. See text and analysis.
70	do.	do.	do.	1,400	130	4		do.	do.	130	do.	do.	See text and analysis.
71	do.	Hatchery inside well	do.	1,400	16			do.	do.		12±	D.	Driven well. See text and analysis.
72	do.	Hatchery outside well	do.	1,400	16			do.	do.		12±	do.	do.
73	Just north of Corry	Corry Water Supply Co.	do.	1,420	50±			do.	do.	50±	flows	PS	24 similar wells. See analysis. Wells spaced about 40 feet apart; water level when pumping about 4 feet below surface of creek.

Drilled wells in Erie County—Concluded

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [d]	Remarks
74	Northern part of Corry [b]	Ed. Marsh	Valley flat	---	402	---	392	Shale	Chemung	392	5	D.	See log in text.
75	Corry	A. A. Williams	Flat	1,420	120	6	110	Sandstone	do.	22	5	do.	Water also encountered at 80 feet in thin-bedded sandstone; 22 feet to bedrock.
76	do. [b]	Sweet	---	---	120	---	---	Shale	do.	100±	flows	do.	
77	Southern part of Corry [b]	Corry Water Supply Co.	---	---	140	6¼	---	Sandstone	do.	20±	40±	---	Clay 20 feet, thin-bedded sandstone 120 feet; small drawdown reported.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] Pennsylvania Second Geol. Survey, Report I⁴, p. 234, 1881.
[d] D—Domestic; Ind—Industrial; PS—Public Supply.

FOREST COUNTY

GENERAL FEATURES

Forest County lies in the northeastern part of the area described in this report and is one of the smallest counties in northwestern Pennsylvania having an area of 424 square miles. It is by far the least developed area of this part of the State. In 1929 it had only 8 manufacturing establishments. In 1930, according to the Federal Census Bureau, it had a total population of 5,180 and was the most sparsely inhabited county in Pennsylvania, having only 12.2 residents to the square mile.

Most of Forest County is drained by Tionesta Creek and Allegheny River; the southeastern part is drained by small tributaries of Clarion River. The county has very little flat land except numerous small upland flats and flood plains along some of the larger streams. The steepest slopes occur along Tionesta Creek and Allegheny River. In the northeast corner of Hickory Township, almost on the Warren County line, one hilltop has an altitude of more than 1,900 feet. This is the highest point in the western half of the county, but as no topographic maps are yet available for the eastern half it is not known whether still higher altitudes are present in that area. The lowest point in the county—less than 1,040 feet above sea level—occurs in the Allegheny Valley where it crosses the western county line. The county therefore has a relief of at least 860 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

No part of Forest County was covered by an ice sheet except possibly an area of less than 1 square mile in the northwest corner of the county. (See pl. 4.) However, two valleys carried outwash materials from the melting ice that lay to the north. Gravel containing igneous pebbles occurs in the Allegheny and Tionesta valleys up to considerable heights above the streams. The higher-level gravel is thin and patchy in occurrence, but the lower gravel at places forms narrow terraces along the streams. A short distance south of the Warren County line, in the Tionesta Valley, a well penetrated 53 feet of "quicksand" and yellow clay, but no appreciable water was encountered until a depth of 100 feet had been reached. Leverett[76] reports glacial gravel forming a terrace about 100 feet above Tionesta Creek near Newtown. In the Allegheny Valley narrow terraces occur at East Hickory and West Hickory and at Tionesta. At West Hickory wells near the middle of the valley penetrate about 70 feet of gravel before reaching bedrock. According to Leverett,[77] "from Warren down to the mouth of the Allegheny the rock floor is usually within 25 feet of the present stream, and it is not known to lie more than 50 feet below the stream at any point." The glacial outwash in some localities will yield moderate supplies of water, but in general it is too thin to be of importance.

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[76] Leverett, Frank, Glacial formations and drainage features of the Erie and Ohio Basins: U.S. Geol. Survey Mon. 41, pp. 238-239, 1902.

[77] Idem, p. 231.

ROCK FORMATIONS[78]

Although the geologic map accompanying this report shows no rocks in Forest County younger than Pottsville, in Jenks Township about 50 feet of the Allegheny formation is present. The oldest rocks in the county occur in the Allegheny Valley at the north county line and are of lower Pocono age. Most of the streams in the area have cut their valleys through the Pottsville formation and exposed the underlying Pocono. With the exception of these valleys and the small areas of the Allegheny formation, all the rocks at the surface are of Pottsville age.

The following section is compiled largely from data given by Ashburner:[79]

Generalized section of Pennsylvanian beds in Forest County

	Feet
Allegheny formation:	
Shale and sandstone	50
Coal	2
Pottsville formation:	
Homewood (Johnson Run) sandstone member	70
Mercer shale member:	
Alton upper coal	3
Shale	5-10
Alton lower coal	4
Connoquenessing (Kinzua Creek) sandstone member:	
Upper sandstone	40
Shale	10
Lower sandstone	40
Sharon shale member, containing 2 feet of coal	10
Olean conglomerate (?)	100

It seems that what is called "Olean" in the above section is erroneously named, because Butts[80] has shown that the Olean conglomerate is absent southeast of a line drawn roughly between Sheffield, in Warren County, and Sharon, in Mercer County. Furthermore Ashburner[81] describes what he calls the "Olean" 1½ mile west of Marienville as containing many flattened pebbles. In Warren County, to the north, both Carll and Butts emphasize the fact that the pebbles in all the sandstones of the Pottsville formation are rounded, whereas the pebbles in all the older rocks are flattish. This fact would also indicate that the Olean of Ashburner is in reality an older bed of Mississippian age.

Very little is known of the detailed geology of Forest County except that of the coal beds. The coals are very irregular, both in occurrence and in thickness, and are usually impure. All the sandstones are massive in places, but they may grade laterally into fine-grained thin-bedded rocks. The so-called "Olean conglomerate" is generally pebbly near the base, the pebbles in some localities being as large as walnuts. The geology is in a general way similar to that described for the adjoining counties. The massive sandstone members of the Pottsville formation generally yield moderate supplies of water to drilled wells, but the water is likely to be high in iron.

[78] The following description is taken mainly from C. A. Ashburner (Pennsylvania Second Geol. Survey Rept. R², pp. 301-326, 1885).

[79] Idem, p. 307.

[80] Butts, Charles, U.S. Geol. Survey Geol. Atlas, Warren folio (no. 172), p. 6, 1910.

[81] Ashburner, C. A., op. cit., p. 316.

The rocks of Forest County are essentially flat-lying, though there is a slight regional dip to the southwest. The southwesterly dip is here and there interrupted by minor synclines and anticlines, the axes of which trend northeast. The structure has not been worked out in detail.

GENERAL GROUND WATER CONDITIONS

As Forest County is but sparsely inhabited, very little demand is made on its ground-water supply. In the rural districts both dug and drilled wells are used, although the dug wells are unsatisfactory because they are likely to go dry in the dry season. Small springs are numerous, and many of them, where favorably located, are used for domestic supplies. The sandstones of the Pottsville formation are the main water-bearers, and in general ample quantities of water can be obtained in the first 50 feet in a loosely cemented white sandstone. Where larger quantities of water are required wells are commonly drilled 100 to 200 feet deep. In places water high in iron is obtained from wells that penetrate coal or coaly shale. Water high in iron is encountered in several wells in the Marienville region.

Although the rocks in Forest County are essentially horizontal, there are minor folds, and water is therefore encountered under artesian pressure in some areas. An oil well drilled 2 miles south of Henry Mills along Tionesta Creek penetrated 21 feet of "quicksand" and 50 feet of shale in which considerable water was encountered under sufficient pressure to cause it to flow at the surface. This well was about 30 feet from the creek. Another well drilled about 300 feet away penetrated 53 feet of "quicksand" and yellow clay and, at a depth of 100 feet in shale, encountered water which rose within 25 feet of the surface.

The village of Endeavor is supplied by springs. A 250-foot well at Endeavor got considerable water in a sandstone at a depth of 60 feet but none between 60 and 250 feet. This well was abandoned because there was evidence of pollution in the water. The West Hickory Tanning Co., supplies most of the water for the village of West Hickory. The water is obtained from three wells 75 feet deep and 8 feet apart. The wells penetrated about 68 feet of gravel in which a small amount of water was encountered and then passed into white sandstone for about 7 feet. The water level is reported to stand about 28 feet below the surface.

The borough of Marienville is supplied with water from two springs during most of the year, but in the dryer season two wells are pumped to supplement the small flow of the springs. One of these wells is 220 feet deep and yields a considerable quantity of water from a depth of about 80 feet. The other well is an old oil well, which is plugged at about 500 feet.

Only two samples of water were collected in Forest County for chemical analysis, and the results are given in the table of analyses in the first part of this report. The samples came from springs, both of which probably derive their supply from beds fairly near the surface and do not give an indication of the chemical character of the water that may be expected in drilled wells. Furthermore, it is reported that drilled wells commonly yield water that contains moderate to large quantities of iron. It is said that in the region around Marienville wells 50 feet or less in depth generally yield water lower in iron than wells of greater depth.

Public water supplies in Forest County

Town	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Endeavor	Wheeler & Dusenbury Co.	Springs			Gravity				None
Marienville	Daniel Harmmon	2 springs, 2 wells[a]	Sandstone in Pottsville formation	Gravity, deep-well pumps	do.			20	do.
Tionesta	Tionesta Water-Supply Co.	Emmett Spring Run			do.	1,575,000	28,500±	65	Hypochlorite of lime
West Hickory	West Hickory Tanning Co.	3 drilled wells		Suction	Direct	None	185,175+	100—	None

[a] Wells used only in dry season.

INDIANA COUNTY

GENERAL FEATURES

Indiana County is the southeasternmost county covered by this report. It has an area of about 829 square miles. In 1930 its population was 75,395. The borough of Indiana, with 9,569 inhabitants, and Blairsville, with 5,296, are the only ones having more than 5,000. In 1930 there were 76 manufacturing establishments and 49 mines in the county.

The northeastern part of Indiana County is drained by the headwaters of the West Branch of Susquehanna River. The remainder of the county drains westward through tributaries of Allegheny River. Mature topography characterizes the county, the land surface being minutely dissected by numerous small streams. Only small upland flats and narrow stretches along some of the stream bottoms remain as flat land. At numerous places along Chestnut Ridge the high points rise more than 2,000 feet above sea level, and at one place in the extreme southeast corner of the county, on the flank of Laurel Ridge, a spur extending into the county from the southeast is almost 2,220 feet above sea level. The lowest point in the county is less than 840 feet above sea level and occurs in the Kiskiminetas Valley at the southwest corner. The total relief of the county is therefore about 1,400 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

As shown in plate 4, Indiana County lies not only well outside the limit of glaciation but also in such a position that none of the streams in the county carried outwash waters from the melting glaciers. The county was therefore not affected by glaciation, and for that reason the surface deposits consist only of thin alluvium along some of the streams or a thin blanket of soil that has resulted from the weathering of the underlying bedrock.

ROCK FORMATIONS [82]

The rocks exposed in Indiana County extend from about 200 feet above the base of the Monongahela formation down to and possibly including a portion of the Catskill formation. The Conemaugh formation is at the surface over the largest part of the county. The largest area of the Monongahela formation in the region covered by this report occurs in the southwest corner of the county, along the Armstrong County line. This area and a few small hilltops east of Blairsville are the only places in the county where the Monongahela formation remains. Along Chestnut Ridge the Allegheny formation is at the surface, and in a few places the Pottsville formation is also exposed. At only two places in the county has erosion cut through the Pottsville formation and exposed the Mauch Chunk and Pocono rocks. These are in the valley of Conemaugh River where it crosses Chestnut and Laurel Ridges.

[82] The descriptions given here were taken mainly from W. G. Platt (Pennsylvania Second Geol. Survey Rept. H⁴, 1878) and G. H. Ashley (Top. and Geol. Atlas of Pennsylvania no. 65. Pennsylvania Geol. Survey, 1926) and from folios of the Geologic Atlas of the United States (U. S. Geol. Survey Geol. Atlas, Indiana folio (no. 102), 1904; Latrobe folio (no. 110), 1904; Elders Ridge folio (no. 123), 1905; Johnstown folio (no. 174), 1910; Barnesboro-Patton folio (no. 189), 1913).

Monongahela formation—The following generalized section of the Monongahela formation is compiled from data given by Stone:[83]

Generalized section of Monongahela formation in Indiana County

	Feet
Benwood limestone member	25±
Shale	80
Sewickley coal	0—5
Fishpot ("Sewickley") limestone member	6
Shale and sandstone	45
Redstone coal	0—3
Pittsburgh sandstone member	40
Pittsburgh coal	6—10

The highest member of the Monongahela formation present in Indiana County is the Benwood limestone, an unfossiliferous gray limestone containing some shale. The Sewickley coal is a rather persistent bed and is separated from the Pittsburgh sandstone by an interval of about 45 feet of shale, sandy shale, and sandstone. At the top of this interval the Fishport (Sewickley) limestone, with an average thickness of about 6 feet, occurs, though it crops out at only a few places. The Pittsburgh sandstone lies on the Pittsburgh coal or may be separated from it by as much as 8 feet of shale. The sandstone is irregular in composition, being massive in some places and shaly in others. Near the Kiskiminetas River it is massive and 30 to 40 feet thick, but when traced to the northeast it becomes thinner and less massive. Near West Lebanon it is a thin-bedded rock about 25 feet thick that rests directly on the Pittsburgh coal. Because of its smaller areal extent the Pittsburgh coal is not so valuable in Indiana County as it is in the region to the south. Its position is shown on plate 5 just above the line marking the contact between the Conemaugh and Monongahela formations.

The formation is of little use as a source of water because of its small areal extent.

Conemaugh formation—The following generalized section of the Conemaugh formation is taken from the Elders Ridge folio:[84]

Generalized section of Conemaugh formation in Indiana County

	Feet
Shale	8
Pittsburgh limestone	5
Fire clay	3
Shale	24
Connellsville sandstone	30
Sandstone, shale, and thin limestone	100
Morgantown sandstone	20
Shale, sandstone, and thin limestone	320
Saltsburg sandstone	45
Sandy shale	40
Mahoning sandstone	50
Shale	5

The Conemaugh formation has a thickness of about 600 to 700 feet. The entire formation is present only in the southwest corner of the

[83] Stone, R. W., U.S. Geol. Survey Geol. Atlas, Elders Ridge folio (no. 123), 1905.
[84] Stone, R. W., op. cit., p. 5.

county in the areas capped by the Monongahela formation. Richardson [85] describes the Conemaugh formation as follows:

As a whole the Conemaugh formation is composed largely of drab and reddish shales, but it is also characterized by the occurrence of important beds of sandstone. Minor beds of limestone and some coal are also included within the formation.

There are four principal sandstones, but these occur as lenses or beds of limited extent and of local thickness instead of uniformly persistent strata. * * * Actual identity in correlation cannot be established because of the noncontinuity of the deposits as traceable beds. In lithologic character these sandstones resemble one another so closely that they cannot be distinguished, but their stratigraphic position serves to identify them. They range from hard, compact, fine-textured white or buff sandstones to friable and coarser-textured, much iron-stained sandstones. Locally these rocks become conglomeratic, the pebbles of quartz occasionally attaining the size of beans. The sandstones vary in thickness from a few feet to 60 or 70 feet. A common measurement when they are well developed is between 20 and 30 feet.

The Connellsville sandstone lying about 40 to 80 feet below the Pittsburgh coal, is massive and thin-bedded and occurs in the southwestern part of the county adjacent to the Pittsburgh coal area. It is underlain by reddish shales and shaly sandstones. Where massive, the Connellsville sandstone is usually grayish, but in places it is iron-stained. The Morgantown sandstone lies about 200 feet below the Pittsburgh coal and about 500 feet above the base of the Conemaugh formation. Like the other sandstones of the formation, the Morgantown is well developed in some places but in others is not easily recognized because of its shaly character. Red shales occur below the Morgantown in numerous places. About 320 feet of thin sandstone, shaly sandstone, and shale containing several thin limestone beds occurs between the Morgantown and Saltsburg sandstones. The top of the Saltsburg sandstone member lies about 150 to 200 feet above the base of the Conemaugh formation. Although the Saltsburg is well developed and massive in many places, it is not persistent as a massive rock. The Mahoning sandstone is the lowest massive sandstone member of the Conemaugh formation. It is separated from the overlying Saltsburg sandstone by about 40 feet of sandy shale. The Mahoning may lie directly on the Upper Freeport coal or may be separated from it by as much as 10 feet of shale. The sandstone, like the other sandstone members of the formation, is massive and prominent in some places but shaly and inconspicuous in others. It attains a thickness of more than 50 feet in some places. The following well logs show the character of the Conemaugh formation:

Log of well 1½ miles southeast of West Lebanon, Pa., (527)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface and loose shale	12	12	Sandstone, greenish	10	155
Shale, red and green	36	48	Sandstone, dark; small flow of gas at 158 feet	15	170
Limestone, shaly (Ames?)	8	56	Shale, sandy, black	17	187
Shale, red and green	41½	97½	Sandstone, light gray	10	197
Sandstone, greenish	4	101½	Limestone, sandy	3	200
Shale, red and green	11	112½	Sandstone, light gray	5	205
Sandstone, green	13½	126	Sandstone, greenish, sandy at base	22	227
Shale, green	19	145			

Well ends in the lower part of the Conemaugh formation.

[85] Richardson, G. B., U.S. Geol. Survey Geol. Atlas, Indiana folio (no. 102), p. 3, 1904.

Log of well half a mile northeast of Clarksburg, Pa., (well 526)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface and loose shale	13	13	Shale, dark	3½	150
Shale, red and green	21	34	Shale, light greenish	5	155
Sandstone, greenish	5	39	Sandstone, greenish	5	160
Shale, green	7	46	Shale, sandy, greenish	4½	164½
Shale, sandy, green	2½	48½	Sandstone, shaly, dark gray	8½	173
Sandstone, greenish	3½	52	Shale, black	2½	175½
Shale, green	6½	58½	Coal	½	176
Sandstone, greenish	18½	77	Fire clay	1	177
Shale, green	5½	82½	Sandstone, shaly, dark gray	8½	185½
Shale, black	4	86½	Shale, limy, black	26½	212
Shale, sandy, black	5½	92	Sandstone, light gray	12	224
Shale, black	32	124	Shale, sandy, dark	2	226
Shale, light, with ore nodules	11	135	Coal, shaly	1½	227½
Sandstone, greenish, and shale, sandy	6	141	Fire clay, sandy	2½	230
Limestone	5½	146½	Sandstone, limy gray	4	234
			Sandstone, shaly	2	236

Well ends in the lower part of the Conemaugh formation.

The sandstone members of this formation, where coarse-grained, generally yield moderate to good supplies of water that may be somewhat high in iron.

Allegheny formation—The Allegheny formation in Indiana County has a thickness of about 300 feet. Although the individual members are irregular both in thickness and in lithologic character, the formation as a whole has a rather uniform thickness. The valuable coal beds of the county occur in this formation. According to Ashley,[86] the average distance between the coals of the Allegheny formation is as follows:

Average distance between coals of the Allegheny formation

	Feet
Between Upper Freeport and Lower Freeport coals	50
Between Lower Freeport and Upper Kittanning coals	45
Between Upper Kittanning and Middle Kittanning coals	65
Between Middle Kittanning and Lower Kittanning coals	35
Between Lower Kittanning and Brookville coals	95

Numerous drill holes short distances apart have shown that the detailed sequence of beds in this formation is very irregular, so that only the most generalized section of the formation can be given. The following section is compiled from data given by Ashley[87] and Richardson.[88]

Section of Allegheny formation in Indiana County

	Feet
Upper Freeport coal	5
Shale, sandstone, clay, and limestone	50
Lower Freeport coal	3
Shale, sandstone, clay, and limestone	45
Kittanning coals, sandstone, and shale	110
Vanport limestone member	2
Shale, sandstone, and thin coal	85
Brookville coal	2
Sandy shale	3

[86] Ashley, G. H., Punxsutawney quadrangle; Top. and Geol. Atlas of Pennsylvania, no. 65, p. 38, Pennsylvania Geol. Survey, 1926.

[87] Ashley, G. H., op. cit., pp. 26-29.

[88] Richardson, G. B., op. cit., p. 3.

The Upper Freeport coal is rather persistent in occurrence and in numerous places attains a thickness of more than 6 feet. As much as 80 feet of dark shale and sandstone occur between the Upper and Lower Freeport coals. The Lower Freeport coal is not persistent, and in the southern part of the county is poorly developed. Shale and sandy shale make up most of the interval between the Lower Freeport coal and the Kittanning coals, but in places a thin limestone or a massive sandstone occurs. The sandstone has a thickness of 63 feet in one bore hole near Graceton. The Kittanning coals are all present in parts of the county, but except locally the lower coal is the only one that is well developed. From the Lower Freeport coal down to the Vanport limestone the rocks consist of shale, sandy shale, and sandstone. Below and in places above the Lower Kittanning coal, massive sandstone occurs. A bed that is probably the Vanport limestone has been seen in a few places and recorded in a few bore holes in Indiana County, but the bed is only a few feet thick and is absent in many localities. The Vanport limestone lies about 85 feet above the base of the Allegheny formation. This interval is mostly filled with shale, but in places the massive Clarion sandstone member is present a short distance above the Brookville coal. The Brookville coal is not well developed in the county except locally. The following is the log of a well in the Allegheny formation:

Log of well in upper part of Allegheny formation 4 miles northwest of Indiana (well 538)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface and gravel	23	23	Limestone	7	111
Shale, greenish	27	50	Shale, sandy, greenish	16	127
Shale, sandy, dark, and sandstone	29½	79½	Sandstone, light gray	27½	154½
Coal (Upper Freeport)	3½	83	Shale, dark	2½	157
Fire clay	5½	88½	Coal (Lower Freeport)	5	162
Limestone	10	98½	Shale, black	4	166
Shale, light	5½	104	Shale, sandy, dark, and sandstone	38	204

Where the sandstone members of the Allegheny formation are coarse-grained they generally yield good supplies of water to drilled wells. The water may be somewhat highly mineralized and is likely to be high in iron.

Pottsville formation—Only a few small outcrops of the Pottsville formation occur in Indiana County. (See pl. 5). The formation has a threefold character—massive sandstone at the top and bottom separated by a shale member. The thickness of the formation ranges from about 100 to 200 feet. The Homewood sandstone, the upper member of the Pottsville, is commonly massive and 30 to 60 feet thick. In places, however, it is thin-bedded and shaly. The Mercer shale member ranges in thickness from a few feet to more than 20 feet. It contains two thin coals, in some localities with accompanying underclays. The Connoquenessing sandstone member is massive to thin-bedded and in places attains a thickness of 100 feet. In many places it is split up by shaly layers, some of which may contain coal. The following is the log of a well that passes through the Pottsville formation:

Log of well at Clymer, Pa., (well 539)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface	20	20	Shale, gray	4	147
Sand, brown	14	34	Sandstone, white	6	153
Sand, black	16	50	Shale, gray	5	158
Shale, white	10	60	Sandstone, white	7	165
Sandstone, white	17	77	Sandstone, brown	3	168
Shale, white	3	80	Sandstone, white	7	1.5
Sandstone, white	12	92	Shale, light	8	183
Shale, dark	3	95	Sandstone, dark	7	190
Sandstone, white	19	114	Sandstone, white	9	199
Sandstone, brown	12	126	Fire clay	3	202
Sandstone, light	10	136	Shale, light	5	207
Fire clay	1	137	Sandstone, brown	8	215
Sandstone, white	6	143			

The well started at a level somewhat above the top of the Pottsville formation. The top of the Pocono probably lies at a depth of about 140 feet.

The sandstone members of the Pottsville formation generally yield considerable water, but over most of the county the formation lies so deeply buried under younger rocks that the water is likely to be highly mineralized and salty.

Mauch Chunk formation and Loyalhanna limestone—In only a few places do the Mauch Chunk formation and the Loyalhanna limestone occur in Indiana County. At least in the northwest half of the county they were removed by erosion before the Pennsylvanian series was laid down. In the southeastern part of the county their occurrence is irregular because they lie below the unconformity previously described. Very little is known of the Mauch Chunk formation and the Loyalhanna limestone in this county. A brief description of them is given elsewhere. They are of little value as sources of water in this county.

Pocono group—The Pocono group is exposed at only two places in Indiana County—in the valley of Conemaugh River where it crosses Chestnut and Laurel ridges. The total thickness of the group is about 1,000 feet, of which about the upper 300 feet forms the Burgoon sandstone. The remainder of the group is made up of shale and sandy shale. The Burgoon sandstone generally yields considerable water, but except where it is relatively near the surface the water is likely to be highly mineralized and salty.

Catskill formation—It is doubtful whether the Catskill formation is exposed at any place in Indiana County. However, where Conemaugh River crosses Chestnut Ridge the Catskill probably lies only a short distance below the surface. Along Laurel Ridge in Cambria County the Catskill is exposed in the Conemaugh Valley, but it does not come to the surface in Indiana County. Phalen [89] gives the following section of the upper part of the formation in this vicinity.

[89] Phalen, W. C., U.S. Geol. Survey Geol. Atlas, Johnstown folio (no. 174), p. 3, 1910.

Section of upper part of Catskill formation in Indiana County

	Feet
Sandstone, chocolate-colored and red	45
Shale, red	20
Sandstone, chocolate-colored	5
Shale, chocolate-colored and vivid green	40±

The Catskill formation is of little use as a source of water in Indiana County.

Structure—The rocks of Indiana County are more highly folded than those of any of the other counties described in this report. The southeast corner of the county lies only about 20 miles from the Allegheny Front, where the intense folds of the Applachain Mountains begin. The general structure of Indiana County consists of a number of roughly parallel synclines and anticlines trending northeast. At least six such major folds have been recognized.

In general the dips along these folds become less and less toward the west in each successive anticline or syncline. In places the dips seem to be steeper on the west side of the axes, but in general the folds are nearly symmetrical. The axis of the Laurel Ridge anticline does not enter the county, but in the southeast corner of the county the rocks dip to the northwest, away from this axis, at the rate of 1,000 feet to the mile. The axis of the Barnesboro syncline passes through Wehrum. West of Wehrum the beds dip to the southeast at the rate of about 200 feet to the mile. The axis of the Nolo anticline passes through Croft and Pinetop and leaves the county at a point about 2½ miles south of Beringer, near where the rocks on the northwest side of the axis dip to the northwest about 300 feet to the mile. The axis of the Brush Valley syncline after passing about a mile east of Brush Valley bends to the northeast, passes near Kenwood and Cookport, and finally leaves the county about 3 miles north of Cherrytree. Northwest of the axis the dip is less than 200 feet to the mile in most places. The Chestnut Ridge anticline, which lies to the west, is the most persistent fold in the Pittsburgh-Huntington structural basin, having a length of more than 300 miles. It extends the whole length of the county, the axis roughly following the crest of the ridge and passing 2 miles east of Graceton, Evans Hill, Strongs Hill, a mile east of Clymer, East Run, and the northeast corner of Indiana County. In the vicinity of Graceton the rocks dip to the northwest more than 400 feet to the mile, but in most places the dips are not so great. Between Chestnut Ridge and the west county line lie a number of minor folds that are not continuous across the county. The axis of the Elders Ridge syncline enters Indiana County near the southwest corner, roughly parallels the county line for about 9 miles, and thence bends somewhat to the east, probably leaving the county about 4 miles southwest of Punxsutawney.

Although the axes of these folds have a general northeasterly trend, they are not straight lines but curve from one side to the other. They also curve in a vertical plane, so that along the crests of the ridges or the bottoms of the troughs the same bed may have a different altitude.

GENERAL GROUND-WATER CONDITIONS

Indiana County is moderately well supplied with ground water. In most places drilled wells yield enough water to supply domestic needs as well as the smaller industries and municipalities. Small springs are numerous and in many places are utilized for domestic supplies. Some of the smaller towns obtain their supply in whole or in part from springs. (See next table.) In this county as in other parts of northwestern Pennsylvania, some dug wells are still in use, but they are gradually being abandoned and replaced by drilled wells. In parts of the county where ample ground water is available the water is high in iron, and the chief problem is therefore one of quality of water rather than quantity.

The sandstones of the Conemaugh, Allegheny, and Pottsville formations and the Pocono group are the best water-bearing beds. Because of the variation of any one member from sandstone to shale within short distances, none of the members have definite water-bearing properties. Two wells but a short distance apart that end in the same member may have entirely different yields. Coal beds are commonly water-bearing, but the water is generally high in iron, especially where the coal has been worked near by.

Because of the structure of the rocks in the county, artesian wells are not uncommon. Richardson makes the following statement regarding artesian water in the Indiana quadrangle:[90]

> The different beds of sandstone receive water at their outcrops, and, being pervious and commonly overlain and underlain by relatively impervious shale, the sandstones are saturated with water and constitute reservoirs. Since there are several synclinal basins within the Indiana quadrangle, artesian water thus becomes available. That is, if holes be sunk to water-bearing sandstones in proper places, water will rise in the holes to different heights and sometimes to the surface, according to the artesian head. This artesian head is determined by the difference in height between the elevation of the outcrop of the sandstones and its elevation in the well. Promising localities for artesian water are in the synclinal areas where sandstone outcrops along adjacent anticlines. In the basin of the Latrobe syncline west of Homer, for instance, artesian water has been found in the Mahoning sandstone, which outcrops on Chestnut Ridge. Large supplies of artesian water, however, should not be expected.

Wells 539 and 540 are northwest of the axis of the Chestnut Ridge anticline. The water in wells between anticlinal and synclinal axes is generally under artesian pressure, although flowing wells are more likely to be obtained along the synclinal axes.

It is reported that in the region around Marion Center most domestic wells are dug and many go dry in the dry season. Both drilled and dug wells are reported to be in use in the Clymer region where most of the drilled wells are less than 100 feet deep. Domestic wells in the Indiana area are reported to be dug 30 to 50 feet deep.

QUALITY OF WATER

Analyses of waters from Indiana County are given on earlier pages. Too few analyses are available to permit any generalization to be drawn regarding the quality of the water. However, water high in iron is reported in many parts of the county, and the removal of this undesirable constituent from otherwise satisfactory waters is probably

[90] Richardson, G. B., op. cit., p. 7.

the chief problem in the county. The treatment of water for the removal of iron is described on page 52. In many parts of the county water high in iron is obtained from wells that penetrate coal beds. In other places, however, wells penetrate coal beds and yield water not excessively high in iron. In localities where the coal has been worked the pyrite in the coal has been more or less exposed to the air, and in these localities oxidation has taken place and allowed some of the iron to go into solution. Where the coal has not been opened to the air, oxidation has not occurred to any great extent, and in these areas wells drilled through coal beds may be expected to yield water not excessively high in iron.

Formerly salt was manufactured near Saltsburg by evaporating water derived from the Pocono group. The wells were 750 to 1,000 feet deep and yielded an unfailing supply. The water was not highly saline, and the process was therefore expensive. The Pocono does not everywhere contain salt water, however, as shown by the wells at Clymer (wells 539 and 540). Clymer, however, is near an anticlinal axis, whereas Saltsburg is in a syncline. Conditions are therefore, more favorable at Clymer for the flushing out of salt water by fresh water than at Saltsburg.

PUBLIC SUPPLIES

About half the towns in the county that have public water supplies depend on ground water, although the larger towns utilize surface water. There appears to be ample ground water to supply the smaller towns for some time to come, although additional wells may have to be drilled to supplement wells and springs now in use.

According to Richardson, [91]

> Seven wells were drilled in Indiana between 1883 and 1891 from which the town was supplied with water. But in 1899 this source proved insufficient, and recourse was had to Two Lick Creek, which now supplies water of a much inferior quality. One of these wells was put down 3,300 feet in search of gas, having been located along the supposed Indiana anticline; the other six range in depth from 175 to 350 feet. Water in them is derived from both the Mahoning and Saltsburg sandstones. In five of these wells the water is reported not to have risen above the horizon at which it was struck, but in two it rose 20 feet.

[91] Richardson, G. B., op. cit., p. 7.

Public water supplies in Indiana County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Barr	-------	Clearfield Bituminous Coal Corp.	Price Run	-------	-------	-------	-------	-------	-------	Chlorine gas
Blairsville	5,296	Municipal	Hillside Run	-------	-------	-------	-------	-------	-------	do.
Brendlinger	-------	Margaret Armerford Coal Co.	Drilled wells	-------	-------	-------	-------	-------	-------	-------
Chambersville	-------	Seneca Coal Co.	do.	-------	-------	-------	-------	-------	-------	-------
Cherrytree	519	Cherry Tree Water Co.	Peg Run	-------	-------	-------	-------	-------	-------	Chlorine gas
Clymer [a]	2,672	Clymer Citizens Water Co.	Drilled well and 5 springs	Pocono group	Deep-well pump	Direct [b c]	270,000±	16,000	110—	do.
Commodore	-------	Clearfield Bituminous Coal Corporation	Hintys Run	-------	-------	-------	-------	-------	-------	do.
Cramer	-------	Penelac Water Co.	Findley Run	-------	-------	-------	-------	-------	-------	do.
Creekside	500	-------	Springs	-------	-------	-------	-------	-------	-------	-------
Ernest	-------	Jefferson & Clearfield Coal & Iron Co.	Drilled wells	-------	-------	-------	-------	-------	-------	Filtered
Graceton	-------	Graceton Coal & Coke Co.	Drilled well	Lower part of Allegheny formation	Air	Direct [b]	33,000	60,000	-------	None
Heilwood	-------	Pine Township Water Co.	4 drilled wells	-------	Deep-well pumps	do.	50,000	47,000	37	do.
Homer City	2,004	Municipal	Cherry Run and Yellow Creek	-------	-------	-------	-------	-------	-------	Filtered
Indiana	9,569	Clymer Water Co.	Two Lick Creek	-------	-------	-------	-------	500,000	-------	do.
Josephine	-------	Josephine Water Co.	Drilled wells	-------	-------	-------	-------	-------	-------	-------
Marion Center [a]	459	Marion Center Water Co.	Spring	Upper Freeport coal(?)	-------	Gravity	500,000	-------	60	None
McIntyre	-------	Rochester & Pittsburgh C. & I. Co.	Drilled well	-------	Deep-well pump	do.	48,000	-------	-------	-------
Robindale	-------	Penelac Water Co.	Hines Run	-------	-------	-------	-------	-------	-------	Chlorine gas
Rossiter	-------	Clearfield Bituminous Coal Corporation	Straight Branch Run	-------	-------	-------	-------	-------	-------	Filtered
Saltsburg	1,035	Municipal	Conemaugh River	-------	-------	-------	-------	-------	-------	do.
Tearing Run	-------	Cosgrove-Meehan Co.	Drilled wells	-------	-------	-------	-------	-------	-------	-------
Tide	-------	Tide Coal Min. Co	Tide Run	-------	-------	-------	-------	-------	-------	Hypochlorite of lime
Wehrum	-------	Buffington W. Co.	Rummels Run	-------	-------	-------	-------	-------	-------	do.

[a] See analysis in table preceding description by counties.

[b] Excess to reservoir.

[c] Direct from well; gravity from springs.

Drilled wells in Indiana County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
526	5 miles west of Jacksonville	Pittsburgh Gas & Coal Co.	Valley	920	236	10	-------	----------	Lower part of Conemaugh	50	15	Industrial	Adequate supply of water. See log in text.
527	1½ miles southeast of West Lebanon	do.	do.	1,000+	227	10	-------	----------	do.	50	20	do.	Adequate supply of water. See log in text.
528	McIntyre[b]	Rochester & Pittsburgh Coal & Iron Co.	----------	---------	150	10	-------	----------	Lower part of Allegheny	65	35	do.	----------
529	2½ miles south of Homer City	Graceton Coal & Coke Co.	Flat	1,060	385	6	310	Sandstone	----------	-----	18	Public supply	Pumps about 300 gallons a minute. See analysis.
530	½ mile northeast of Homer City	Rochester & Pittsburgh Coal & Iron Co. (Lucerne mine)	Valley	1,040	185	10	-------	----------	Upper part of Allegheny	60	20	Industrial	----------
531	3 miles northeast of Homer City	T. N. Robinson	Hillside	1,620±	-------	-----	165	Sandstone	Lower part of Allegheny	-----	------	----------	Old gas well; water also encountered at base of Lower Freeport coal at a depth of 61 feet.
532	Indiana[b]	Clymer Water Co.	----------	---------	-------	-----	-------	do.	Lower part of Conemaugh	-----	----	----------	See text.[c]
533	do.[b]	Indiana State Teachers' College	Hilltop	1,300±	190	-----	-------	do.	Mahoning	-----	80±	Public supply	Some water also comes from Saltsburg sandstone; water rose 120 feet when encountered.[c]
534	do.	do.	do.	1,300±	210	-----	-------	do.	do.	-----	80±	do.	do.
535	do.	do.	do.	1,300±	200±	-----	-------	do.	do.	-----	80±	do.	do.
536	1 mile west of Indiana[b]	Harry McCreary	Valley	---------	154	8	-------	Sandstone (?)	----------	20	12	Industrial	Pumps 75 gallons a minute.[c]
537	do.	do.	do.	---------	154	8	-------	do.	----------	20	12	do.	do.

Drilled wells in Indiana County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
538	4 miles northwest of Indiana	Jefferson & Clearfield Coal & Iron Co.	do.	1,060	204	8	-------	----------	Upper part of Allegheny ---	25	------	do.	Adequate supply of water. See log in text.
539	Clymer --------	Clymer Citizens Water Co.	do.	1,220	215	8	175	Sandstone	Pocono ----	-----	------	Abandoned --	This well flowed until well 540, 125 feet to the southwest, was drilled to a depth of 175 feet. See analysis and log.
540	do.	do.	do.	1,220	240	10	175	do.	do.	34	------	Public supply	Flowing 17 gallons a minute on Oct. 10, 1929; drawdown reported to be 4 feet when pumping 350 gallons a minute. See analyses.
541	Hellwood ------	Pine Township Water Co., well 1 .	do.	1,536	130	10	40	----------	Allegheny -	100	40	do.	Yields 12,000 gallons a day.
542	do.	Pine Township Water Co., well 2	do.	1,535	125	10	40	----------	do.	60	------	do.	do.
543	do.	Pine Township Water Co., well 3	do.	1,540	115	10	40	----------	do.	80	40	do.	do.
544	do.	Pine Township Water Co., well 4	do.	1,537	130	10	40	----------	do.	100	40	do.	do.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] U. S. Geol. Survey, Geol Atlas, Indiana folio (no. 102), p. 7, 1904.

JEFFERSON COUNTY

GENERAL FEATURES

Jefferson County lies in the extreme eastern part of the region covered by this report and has an area of about 666 square miles. The population in 1930, according to the United States Census, was 52,114, compared with 62,104 in 1920. Punxsutawney, with 9,266 inhabitants, is the only borough in the county having a population larger than 5,000. In 1930 there were 81 manufacturing establishments and 32 mines in operation within the county.

All of Jefferson County drains to the southwest—the northern part by Clarion River, the central part by Redbank Creek, and the southern part by Mahoning Creek. The highest land in the county lies along the Clearfield County line, in Gaskill Township, where one hill rises more than 2,220 feet above sea level. The lowest point in the county as shown by the topographic maps is about a mile south of Hamilton, where Mahoning Creek crosses the Jefferson-Indiana County line, at about 1,160 feet above sea level. At the northwest corner of the county, where Clarion River enters Clarion County, its altitude is probably as low as that of Mahoning Creek at the point mentioned, if not lower. The maximum relief is therefore more than 1,000 feet. In general, however, the hilltops rise from 300 to 500 feet above the adjacent valleys.

The county is essentially a region of mature topography or sloping land, there being only small areas of nearly level land on some of the ridges and knolls and along the larger valleys.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

Jefferson County lies outside the area that was affected by the great ice sheets. Not only was no till deposited in the county but none of the drainage lines carrying water from the melting glaciers crossed this area. Along some of the stream bottoms alluvium is present, but such deposits are thin. The upland areas are mantled by a thin cover of soil that has been produced by the weathering of the underlying bedrock.

ROCK FORMATIONS[92]

The rocks exposed in Jefferson County extend from about 400 feet above the base of the Conemaugh formation down to and including about 100 feet of the Pocono group. Except for a few outliers, the Conemaugh formation occurs only in a broad band a few miles wide, extending roughly from Punxsutawney to Sykesville. The Pottsville formation crops out in the northern part of the county as well as in the valley of Redbank Creek and its tributaries. In the southeast corner of the county the Chestnut Ridge anticline brings a small area of the Pottsville formation to the surface. Clarion River, which forms the north county line, has cut through the Pottsville and exposed the underlying Pocono. Toby Creek from Brockwayville north also exposes the Pocono. The Allegheny formation crops out over the rest of

[92] The descriptions given here are taken mainly from W. G. Platt (Geology of Jefferson County: Pennsylvania Second Geol. Survey Rept. H,[6] 1881) and G. H. Ashley (Punxsutawney quadrangle: Top. and Geol. Atlas of Pennsylvania, no. 65, Pennsylvania Geol. Survey, 1926).

the county and has a greater areal distribution than any other formation.

Conemaugh formation—The following generalized section[93] shows the character of the Conemaugh formation in Young Township:

Generalized section of Conemaugh formation in Jefferson County

	Feet		Feet
Limestone.		Red shale	2
Shale	15	Interval	30
Coal and shale	Thin bed	Sandstone, greenish	10
Concealed	75	Shale	10
Coal, slaty	3	Coal	Thin bed
Concealed	80	Shale	65
Red shale	6	Limestone, black	(?)
Interval	10	Slate, black	20
Shale and thin-bedded sandstone	27	Mahoning sandstone	50

Good exposures of the Conemaugh formation are rare because the rocks weather easily, and the outcrops are therefore concealed by the weathered material. The formation is very irregular in character, but shale makes up most of the rocks. The shale is sandy, and the sandstone is shaly. Generally the shale has a greenish tint that is not found in the shale of the underlying Allegheny formation. There are all gradations from soft shale to resistant conglomerate. The description of the Conemaugh formation given for Indiana County applies in a general way to the formation in Jefferson County. The following log of well 495, near Sykesville, shows the character of the lower part of the Conemaugh formation:

Log of well 495, in lower part of Conemaugh formation at Sykesville

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Surface and loose shale	16	16	Shale, sandy, black	5	135
Shale, drab	9	25	Sandstone, bluish	3	138
Shale, sandy, drab	6	31	Shale, bluish	1	139
Shale, bluish	26	57	Fireclay and shale, red	6	145
Shale, black	10	67	Limestone	3	148
Sandstone, shaly	5	72	Shale, sandy, bluish, and sandstone; water at 151 feet	14	162
Shale, bluish	21	93	Sandstone, gray	3	165
Shale, black	4	97	Shale, sandy, bluish	8½	173½
Limestone	2	99	Shale, black	8	181½
Shale, sandy, bluish	3	102	Coal and bone	½	182
Sandstone, gray	3½	105½	Fire clay	5	187
Limestone	3	108½	Shale, bluish	5½	192½
Shale, sandy, bluish	11½	120	Sandstone, gray	11½	204
Shale, bluish; water at 130 feet	10	130			

Because of its small areal extent, the Conemaugh formation is of little value as a source of water, although in the southeastern part of the county, where its greatest thickness remains, the sandstone members generally yield moderate supplies of water.

Allegheny formation—The following is a record of a well drilled in Sykesville by Morris Smith, of Reynoldsville, for the Buffalo & Susquehanna Coal & Coke Co.

[93] Platt, W. G., op. cit., p. 20.

Log of well of Buffalo & Susquehanna Coal & Coke Co., Sykesville (well 496)

	Ft.	In.
Gravel and soft clay	33	
Shale, dark bluish	8	
Shale, red and green	9	6
Shale, greenish	5	
Shale, sandy, greenish	10	
Shale, dark	3	6
Shale, black	7	7
Coal	1	9
Fire clay	7	8
Shale, light	15	
Shale, sandy, bluish	7	
Sandstone, shaly	4	
Shale, sandy, dark	8	
Shale, sandy, black	14	
Sandstone, light gray	19	
Shale, black	5	9
Coal (Lower Freeport)	4	9
Fire clay	1	6
Shale, light bluish	3	
Limestone	6	
Sandstone, bluish	8	
Shale, sandy, bluish	3	
Shale, bluish	3	6
Coal	1	6
Fire clay	5	
Sandstone, shaly	14	
Shale, black	4	
Coal		9
Fire clay	2	3
Sandstone, shaly	9	
Shale, dark	14	
Sandstone, gray, limy at top	9	
Shale, sandy, dark	17	
Coal, bony	3	
Fire clay	6	
Shale, sandy, dark gray	8	
Shale, black	3	
Shale, sandy, dark	5	
Sandstone, gray, limy at base	7	
Shale, sandy, dark	7	
Shale, black	14	
Coal		3
Shale, sandy, and sandstone, dark	10	9
Shale, dark	5	4
Coal, bony	1	8
Fire clay	2	6
Sandstone, white	23	6
Fire clay, sandy	7	
Sandstone, gray	3	
Shale, dark	1	
Limestone	4	
Shale, black, and bone	2	
Sandstone, clayey	3	
Shale, sandy, dark	15	
Shale, dark	8	3
Coal	1	6
Shale, sandy, and sandstone, dark	14	3
Shale, black, and bone	1	6
Fire clay	2	
Sandstone, white (Homewood)	31	6
Total depth	456	

Mr. Smith appears to keep very careful records of the wells he drills, and many of them he has compared with records of near by diamond-core records so that the log as given above is probably accurate. If the correlation made for the Lower Freeport coal and the Homewood sandstone in the log is correct, the top of the Allegheny formation lies about 120 feet below the surface, the horizon of the Upper Freeport coal being either in the 8 feet of dark sandy shale or in the 14 feet of black sandy shale. The thickness of the Allegheny formation in this record is then about 300 feet. This thickness is rather uniform throughout the county, and the sequence of the members making up the formation is similar in this county to that in the adjoining counties, though many minor differences occur. The Upper Freeport coal is usually present where it has not been eroded away, but in many places it is thin. The Lower Freeport coal—the best developed and most valuable coal bed in Jefferson County—lies about 45 feet below the Upper Freeport coal. The Freeport sandstone member is not well developed in most of the county, but a little west of Reynoldsville it is massive and 30 to 40 feet thick. The Upper Kittanning coal lies about 95 feet below the Upper Freeport coal. The Middle Kittanning coal, which lies about 50 feet below the Upper Kittanning coal, is best developed in Knox, Oliver, and Rose townships. The Lower Kittanning coal is rather persistent in the county but is well developed only in Clover, Ringgold, Knox, Oliver, and Snyder townships. It lies about 90 feet above the Brookville coal.

The Vanport limestone, though not the persistent bed in Jefferson County that it is in the area to the west, is present in most of the county except the southeastern and northwestern parts, its absence in the northwest being due to its removal by erosion. It is well developed in the valley of Redbank Creek. Its greatest thickness is about 6 feet,

and in many places it is cherty and impure. The Buhrstone iron ore, not more than 1 foot thick, commonly overlies the Vanport. The Clarion coal generally lies about 30 feet above the Brookville coal. The Brookville coal is well developed only in parts of Clover, Knox, Rose, Pine Creek, and Washington townships.

The log of the well at Sykesville shows the entire thickness of the Allegheny formation. Most of the formation consists of shale, sandy shale, sandstone, and fire clay. The sandstone members of the Allegheny formation, where massive, generally yield moderate supplies of water that may be somewhat high in iron.

Pottsville formation.—The following is the combined record of two near-by holes 2 miles southeast of Emrickville, drilled by Morris Smith, of Reynoldsville. The wells are about 1,500 feet apart. One of them ends in the Homewood sandstone and the other one starts in the same rock.

Combined log of wells 2 miles southeast of Emrickville (No. 483)

	Ft.	In.
Allegheny formation, 117+ feet:		
Surface material	1	9
Shale, brown, sandy	24	9
Shale, dark	8	6
Shale, black	10	8
Coal		10
Fire clay	4	6
Sandstone, gray and brown	7	
Limestone (Vanport)	2	
Shale, brown, limy	3	
Shale, dark	9	6
Coal	1	8
Fire clay	5	4
Sandstone, gray		6
Shale, dark	8	
"Slate," black	9	3
Sandstone, dark	3	
"Slate," black with streak of coal at base	14	9
Fire clay	2	
Pottsville formation:		
Homewood sandstone member, 63± feet:		
Sandstone, gray (Bottom of one well)	3	5
Sandstone, light gray	31	6
Sandstone, dark gray	17	
Sandstone, white, pebbly	11	6
Mercer shale member, 60 feet:		
Shale, dark	3	8
Coal, bony	2	
Fire clay	4	10
Coal	1	3
Fire clay	5	9
Pottsville formation—continued		
Shale, gray, sandy	11	
Fire clay, very white	9	
Fire clay, sandy	9	
Shale, black	7	6
Coal	1	6
Fire clay	1	
Shale, light gray, sandy	3	
Connoquenessing sandstone member, 177± feet:		
Sandstone, dark	6	
Sandstone, light gray	13	
Sandstone, white	23	
Shale, dark, sandy	2	8
Coal		1
Flint clay, sandy	6	
Shale, dark, sandy	4	3
Flint clay	7	6
Shale, dark	3	
Sandstone, dark gray	2	6
Shale, dark sandy	4	
Sandstone, dark gray	2	
Flint clay	7	
Sandstone, white, very hard	45	6
Sandstone, light gray, and shale, sandy	4	
Sandstone, light gray	10	6
Pocono group, 97± feet:		
Sandstone, white	72	
Sandstone, red and gray	10	
Shale, green, sandy	28	
Shale, red	9	
Limestone	6	
Sandstone, light gray	8	

The upper 117 feet of the beds shown in the record comprises the lower part of the Allegheny formation. The base of the Pottsville formation as indicated in the record is doubtful. The average thickness of the formation in this area is about 300 feet. In the well record such a thickness would bring the base of the formation somewhere in a thick group of sandstone. It appears, therefore, that in this record both the base of the Pottsville and the top of the Mississippian series consist of sandstone, and for this reason it is difficult to determine the true position of the contact. The Connoquenessing sandstone member, as shown in this record, consists of an upper and a lower sandstone with intervening shale. This is also true of the Connoquenessing in parts of the areas to the north and south of Jefferson County.

The Homewood sandstone has an average thickness of about 50 feet, but in places it attains 75 feet. It is generally massive and coarse-grained and in some localities is conglomeratic. The Mercer shale member is usually at least 30 feet thick. It commonly contains two or three thin coals, of which the upper one is the most valuable. The upper sandstone of the Connoquenessing member is well developed in the valley of Redbank Creek. It attains thicknesses of 75 feet or more in places. Little is known of the rocks below this sandstone, for their area of outcrop is small.

The sandstone beds of the Pottsville formation can generally be relied upon to yield good supplies of water, although it may be highly mineralized and high in iron.

Pocono group.—Although some red shales have been encountered in drilling in Jefferson County, the true Mauch Chunk is probably absent in most if not in all of the county. Very little is known of the rocks of the Pocono group, for in the area of their outcrop along the Clarion River clean exposures are rare. From well records, however, the Burgoon sandstone, the top formation of the group, seems to be of the same general character as in the adjoining areas.

Structure.—Platt [94] described seven anticlines and six synclines in Jefferson County. The geologists of the Second Geological Survey of Pennsylvania assumed that the axes of the folds west of the Allegheny Front were essentially straight lines. However, in the region south of Jefferson County it has been shown by more detailed mapping that the axes of the folds are not straight but curve and change direction considerably. The axes of the folds as mapped by Platt in this county are therefore probably not very accurate in their details. They trend about N. 40° E. The axis of the Chestnut Ridge anticline just crosses the southeast corner of the county. Between this anticline and the anticlinal axis that crosses the northwest corner of the county there are five anticlines whose axes lie about 5 miles apart, though the first one northwest of Chestnut Ridge is about 9 miles distant. Between these anticlines the rocks bend down, forming synclines. The dip of the rocks along these folds is not great, in general becoming less toward the northwest. In addition to the northwest and southeast dips along these folds there is a regional dip of all the rocks to the southwest.

GENERAL GROUND-WATER CONDITIONS

Jefferson County is well supplied with ground water. Small springs are numerous and are utilized in many places where they are favorably located. The yield of most of these small springs varies considerably with the wet and dry seasons, and they are therefore not a reliable source of water. In the rural areas and the smaller towns both dug and drilled wells are in use, although the dug wells in many places are not reliable and are therefore gradually being replaced by drilled wells. In many parts of the county the ground water available is adequate in quantity to meet the requirements, but it is high in iron, and the chief problem is therefore that of procuring water low in iron either by further drilling or by treatment for the removal of the iron.

Sandstones are by far the largest producers of water. The sand-

[94] Platt, W. G., op. cit., pp. xix-xxviii.

stones of the Conemaugh, Allegheny, and Pottsville formations are all good water-bearers in some areas, but in other areas wells that reach the horizon of these sandstones yield only small quantities of water. This condition exists because of the variation of most of the rocks in the county from sandstone to shale in short distances. None of the sandstones, therefore, have definite water-bearing properties.

The structure of the rocks in Jefferson County is such that in many places wells encounter water under artesian pressure. In most places this pressure is not sufficient to make the water flow at the surface, but it is not uncommon to encounter water that rises 10 feet or more above the level at which it was struck. These artesian wells are located between the anticlinal axes. Wells near the synclinal axes generally contain water that is under the greatest artesian pressure, and therefore, at these locations flowing wells are more likely to be obtained. In the region around Emrickville, according to one driller, wells generally encounter water that rises 30 feet above the point at which it is struck. Wells 479, 481, 486, 491, and 498 encountered water that was under artesian pressure. In wells 479 and 491 the artesian pressure was sufficient to produce a flow at the surface.

Dug wells are in use in the Adrian area that range in depth from 14 to 47 feet. In the Reynoldsville area some dug wells are still in use, but drilled wells are mostly used in the rural vicinity. In Falls Creek a few private wells are in use, most of them drilled to a depth of about 60 feet, at which a white water-bearing sandstone is encountered. A few industrial plants have their own wells, but the water is high in iron, and the city water is therefore used. In the Summerville region a number of shallow dug wells are in use. The two springs of the Peoples Water Co. issue from joints in the massive Vanport limestone. In the wet season these springs supply the needs of the town, but in the dry season the wells are used to supplement them. The limestone in this region is 6 to 8 feet thick and is well jointed.

QUALITY OF WATER

Analyses of waters from Jefferson County are given on pages preceding the county descriptions. Here, as in many other parts of northwestern Pennsylvania, the ground water is in general rather high in iron. The treatment of water for the removal of iron is described on another page. Three of the analyses given in the table (476, 477, and 502) show high sodium chloride and high total solids. These wells range in depth from 170 to 280 feet, and salt water may therefore be expected at relatively shallow depths in parts of Jefferson County. It is reported that in many parts of the county where no samples of water were collected for analysis, water high in iron is common, and it therefore appears that this condition exists over much of Jefferson County.

PUBLIC SUPPLIES

Several of the smaller towns in the county obtain their public supplies from drilled wells or springs. Reynoldsville is the largest town in the county utilizing ground water, although during a part of the year its supply probably includes some surface water. There appears to be ample ground water to supply the needs of the smaller towns for some time to come, although additional drilling may be necessary to supplement the present supplies as the towns increase in population.

Public water supplies in Jefferson County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Adrian (mine)		Rochester & Pittsburg Coal & Iron Co.	2 drilled wells				28,000	60,000±		
Big Run	795		Consolidated Water Co. of Punxsutawney							
Brockway	2,690	Brockway Crystal Water Co.	Whetstone Run			Gravity		60,000		
Brookville	4,387	Municipal	North Fork Creek			do.	2,000,000			
Conifer[a]		Allegheny River Mining Co.	2 drilled wells			do.	20,000			
Falls Creek	1,231	Municipal	Falls Creek				125,000	60,000		
Lindsey			Consolidated Water Co. of Punxsutawney							
Pardus		Panther Run Coal Co.	1 spring							
Punxsutawney	9,206	Consolidated Water Co. of Punxsutawney	Clover Run, East Branch Mahoning Creek				91,200,000	1,500,000		
Reynoldsville[ab]	3,480	Municipal	6 drilled wells, Pitch-pine Run	Lower part of Allegheny formation	Deep-well pumps; air	Gravity	320,000[c]	200,000	118	Chlorine gas
Summerville[de]	1,202	Peoples Water Co.	2 drilled wells, 2 springs	Pottsville formation and Vanport limestone	Deep-well pumps	do.	100,000	60,000		None
Sykesville[d]	2,103	Municipal	4 drilled wells	Lower Conemaugh formation	do.	Direct[f]	85,000		85—	
West Reynoldsville			Reynoldsville municipal supply							

[a] See record of wells in following table.
[b] Wells used about 3 months of year; one large spring leading to impounding reservoir is reported to supply needs most of the year.
[c] 2 impounding reservoirs.
[d] See analysis and record of wells.
[e] Wells not used in wet season of year.
[f] Excess to reservoir.

Drilled wells in Jefferson County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
475	½ mile northwest of Summerville	Waldorf mine	Valley	1,160+	34	6	-------	Sandstone	Homewood(?)	10	12	Industrial	Surface 5 feet, gray sandstone 29 feet; small drawdown.
476	½ mile east of Summerville	Peoples Water Co., well 2	Hillside	1,230±	280	10	-------	----------	Pottsville	-----	35±	Public supply	See analysis.
477	do.	Peoples Water Co., well 3	do.	1,240±	212	10	-------	----------	do.	-----	------	do.	do.
478	Conifer[b] ------	Allegheny River Mining Co.	do.	1,370	185	6¼	-------	Sandstone	----------	40	------	do.	Pumps 15,000 gallons a day.
479	3 miles south of Brookville	----------	----------	1,360	------	-----	-------	----------	----------	-----	Flows	Domestic	Flowed 4 gallons a minute July 17, 1929.
480	1 mile northwest of Emerickville	John Hatten	Hilltop	1,620±	93	5⅝	-------	----------	Lower part of Allegheny	-----	------	do.	----------
481	Emerickville	Charles Zimmerman	do.	1,700+	66	5⅝	60	Shale	Middle of Allegheny	20	30±	do.	Small drawdown.
482	3½ miles west of Reynoldsville	Hydraulic Press Brick Co.	Valley	1,360—	136	8	-------	----------	Pottsville	37	------	Industrial	do.
483	2 miles southeast of Emerickville	----------	Hillside	----------	400	-----	-------	----------	----------	-----	------	----------	Test hole. See log.
484	3 miles northwest of Reynoldsville	C. A. Hetrick	do.	1,840	47	5⅝	-------	Sandstone	Upper part of Allegheny	14	30	Domestic	Well at house; adequate supply of water.
485	do.	do.	do.	1,840±	42	5⅝	-------	do.	do.	14	------	do.	Well at barn.
486	1 mile northeast of Reynoldsville	Reynoldsville Borough (ice plant)	Valley	1,420+	297	10	225	do.	Homewood (?)	28	30	Industrial	Water stood 5 feet from the surface until a depth of 225 feet was reached, when it dropped to 30 feet; at a depth of 200 feet well was bailed dry, 12 gallons to the bailer; at 297 feet it could not be bailed dry.
487	½ mile east of Reynoldsville	Reynoldsville Borough	do.	1,400±	210	10	-------	do.	Lower part of Allegheny	-----	60	Public supply	Six old wells.

488	Reynoldsville	do.	do.	1,400±	110	14	-------	do.	do.	42	14	do.	Drawdown of about 11 feet by pumping 15 gallons a minute for 34 hours.
489	do.	do.	do.	1,400±	140	-----	-------	do.	do.	-----	------	----------	----------
490	do.	do.	do.	1,400±	128	-----	-------	do.	do.	-----	------	----------	----------
491	1½ mile southeast of Reynoldsville	----------	Valley ---	1,400—	80	8	75	----------	Middle of Allegheny	30	Flows	----------	Another well nearby with small drawdown, but it does not flow.
492	Sykesville ------	Sykesville Borough, well 1	Hillside -	1,460±	171	8	130	Shale	Lower part of Conemaugh --	-----	20±	Public supply	Pumped 15 gallons a minute; water also encountered at depths of 65 and 105 feet. See analysis.
493	do.	Sykesville Borough well 2	do.	1,440±	140	8	100	----------	do.	-----	------	Abandoned	Water also at 63 feet.
494	do.	Sykesville Borough well 3	do.	1,500±	247	8	-------	----------	do.	-----	------	do.	Large drawdown.
495	do.	Sykesville Borough well 4	do.	1,480±	204	8	151	Sandy shale	do.	-----	------	Public supply	Pumped 15 gallons a minute; when drilled tested 39 gallons a minute for 10 hours; water also encountered at depth of 130 feet in shale. See analysis and log of well.
496	do.	Buffalo & Susquehanna Coal & Coke Co.	Valley --	1,361	456	-----	-------	----------	Lower part of Allegheny --	-----	------	Industrial	See log of well.
497	South of Sykesville[b]	Sykesville Borough	do.	1,390	349	8	-------	----------	do.	-----	------	----------	Pumped 5 gallons a minute when drilled.
498	½ mile north of Wishaw ------	Jefferson & Clearfield Coal	do.	1,500	161	8	100±	Sandstone	do.	30	20	Industrial	Small drawdown.
499	1½ miles east of Big Run ----	Consolidated Water Co. of Punxsutawney	do.	1,320	156	5⅝	-------	Sandstone (?)	Homewood	-----	------	Public supply	Has been pumped continuously for as much as 1½ months at 313 gallons a minute with no appreciable effect on quantity of water; well used only in dry season; water reported to be high in iron.
500	1 mile southeast of Big Run[b]	Big Run mine --	Hillside -	----------	102	8	-------	Sandstone	Upper part of Allegheny ---	-----	------	Industrial	Two other wells nearby are 94 and 95 feet deep.
501	2 miles northeast of Punxsutawney	Rochester & Pittsburgh Coal & Iron Co.	do.	1,360±	293	-----	184	do.	Mahoning -	-----	------	None	A pump hole through which mine water is pumped; large quantity of water at 184 feet; also at 282 feet in Butler sandstone.
502	Punxsutawney	Punxsutawney Ice Co. -------	Valley --	1,240—	170	4	-------	----------	Upper part of Allegheny ---	-----	------	Industrial	Pumped by air; adequate supply of water. See analysis.
503	do.	do.	do.	1,240—	140	6	-------	----------	do.	-----	------	do.	Adequate supply of water. See analysis.
504	½ mile west of Hamilton	W. R. Depp ---	Hillside -	1,240±	-------	-----	185	Sandstone (?)	Clarion (?)	-----	------	----------	Old gas well.

[a] Altitude taken from nearest 20-foot contour.

[b] Not located on map.

LAWRENCE COUNTY

GENERAL FEATURES

Lawrence County lies along the Ohio State line between Mercer and Beaver Counties. It is the smallest county covered by this report, having an area of only 360 square miles. According to the United States Census, the county had a population of 97,258 in 1930, which makes it one of the most densely inhabited counties in northwestern Pennsylvania. New Castle, with a population of 48,674, and Ellwood City with 12,323 (of whom 1,355 were in Beaver County), are two of the twenty largest cities and boroughs in the area here described. The county had 120 manufacturing establishments in 1930.

Lawrence County is drained by Beaver River and its tributaries, the Shenango and Mahoning rivers and Neshannock and Slippery Rock creeks. Shenango and Mahoning rivers flow in valleys deeply filled with glacial drift. Beaver River in its lower portion flows in a rock valley that has been entrenched into an old gradational plain that was cut by the old Beaver River when it flowed to the north.



Plate 8A.—Pockets of gravel incorporated in laminated silt 1 mile north of Pulaski, Lawrence County, Pa.

In these places a rock-cut terrace stands about 120 feet above the river. In the northeast corner of the county the lowlands are poorly drained, and swamps are numerous.

The county is characterized by moderate slopes with extensive areas of rolling land. The steepest slopes occur along the valley of Slippery Rock Creek in the eastern part of the county, where the valley walls rise more than 400 feet in a distance of less than a quarter of a mile. The highest hills along the eastern county line are more than 1,400 feet above sea level, but along the Ohio State line the highest knobs are about 200 feet lower. The highest point in the county is about 1½ miles south of Princeton, where two knobs are more than 1,440 feet above sea level. The lowest point in the county is in Beaver River where it crosses the south county line, less than 760 feet above sea level. The maximum relief of the county is therefore more than 680 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

All but the southeast corner of Lawrence County was covered by ice during the glacial epoch. The glacial boundary shown in plate 4 is in general not marked by a prominent terminal moraine, as it is



Plate 8B.—Exposure of glacial silt 1 mile north of Pulaski, Lawrence County, Pa.

farther to the north. The drift on the upland areas is generally thin. However, the larger valleys, particularly those of the Beaver, Mahoning, and Shenango rivers, are deeply filled with glacial outwash throughout most of their courses. The extent and thickness of the valley filling is shown in plate 4. It consists of clay, sand, and gravel stratified in irregular fashion, at some localities being composed almost entirely of clay and "quicksand" but at others containing numerous layers or lenses of sand and gravel. (See plates 8A and 8B.)

The sand and gravel of the glacial outwash generally yield moderate

to large quantities of water to drilled wells that are properly screened and developed. The water is likely to be somewhat hard.

ROCK FORMATIONS[95]

The rocks exposed in Lawrence County extend from a little above the Buffalo sandstone member of the Conemaugh formation down to about 40 feet below the base of the Pottsville formation. The surface rocks in most of the county, except the glacial drift, belong to the Allegheny formation. In the southern part of the county the highest hills are capped with the lower members of the Conemaugh formation, the largest areas of which occur in Perry and Big Beaver townships. From New Castle north along the Shenango Valley the river has completely cut through the Pottsville formation and into the Cuyahoga formation of the Pocono group. In the valley of the Mahoning River from a point a few miles southeast of Edinburg to the Ohio State line, the river has likewise cut through the Pottsville formation. In the northwest corner of the county the surface rocks are mainly Pottsville. Except as noted above, the valleys of Mahoning and Shenango rivers and Neshannock Creek are cut into the Pottsville formation. Slippery Rock Creek, where it enters the county, and Connoquenessing Creek, for a few miles near its mouth, have also cut into the Pottsville.

Conemaugh formation.—The following generalized section of the Conemaugh formation in Lawrence County is compiled from data given by White[96] and DeWolf:[97]

Generalized section of Conemaugh formation in Lawrence County

	Feet
Buffalo sandstone	30
Shale	0 — 5
Brush Creek coal	0 — 3
Fire clay	0 — 5
Limestone	0 — 5
Mahoning sandstone	10 — 56
Shale	0 — 6

Because the areal distribution of the Conemaugh formation in Lawrence County is small and because the formation is, in a general way, similar to the Conemaugh of the region to the south, the reader is referred to the description given in the Beaver County section. The Conemaugh formation is of little value as a source of water in Lawrence County.

Allegheny formation.—The following generalized section of the Allegheny formation in Lawrence County is compiled from data given by White[98] and DeWolf:[99]

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[95] The descriptions given here are taken mostly from I. C. White (Pennsylvania Second Geol. Survey Rept. Q[2], 1880); and F. W. DeWolf, New Castle Quadrangle (Top. and Geol. Survey Atlas of Pennsylvania, No. 5, 1929).

[96] White, I. C., op. cit., pp. 22-26.

[97] DeWolf, F. W., op. cit., pp. 30-34.

[98] White, I. C., op. cit., pp. 27-51.

[99] DeWolf, F. W., op. cit., pp. 35-46.

Generalized section of Allegheny formation in Lawrence County

	Feet		Feet
Upper Freeport coal	0— 6	Lower Kittanning coal	1— 3
Fire clay	0— 3	Fire clay	0—10
Upper Freeport limestone	0— 8	Kittanning sandstone	0—45
Shale	0—75	Vanport limestone	0—25
Butler sandstone	0—80	Coal, Scrubgrass	0— 2
Shale with iron nodules	0—80	Clay	0—10
Lower Freeport coal	0— 6	Sandstone	0—10
Fire clay	0— 3	Shale	10—45
Lower Freeport limestone	0— 3	Sandstone	0—10
Shale and Freeport limestone	30—60	Clarion coal	0—1½
Upper Kittanning coal	0— 4	Fire clay	0— 5
Sandstone and shale	10—40	Shale, with iron nodules	15—40
Middle Kittanning coal	1— 4	Brookville coal	0— 4
Fire clay	0—10	Fire clay and shale	0—20
Shale with iron nodules	20—50		

The Upper Freeport coal, which marks the top of the Allegheny formation, has only a small areal distribution and is very irregular both in occurrence and in thickness. In places the overlying Mahoning sandstone rests directly on the coal, and in a few places the coal is partly cut out by the sandstone. The interval of 60 to 70 feet between the Upper and Lower Freeport coals in places contains a massive sandstone known as the Butler sandstone member. In general the Butler is not massive, but between Wampum and the Beaver County line it is a hard, coarse whitish rock that contains a few small pebbles. The Butler sandstone may rest directly on the Lower Freeport coal, or the two may be separated by shale. The rocks between the Lower Freeport and Upper Kittanning coals consist, in most places, of shale or thin-bedded sandstone. However, in some localities the sandstone becomes massive and occupies most of the interval. In North Beaver Township, near the State line, the sandstone is 60 feet thick, the upper part massive and the lower part thin-bedded. Between the Upper Kittanning coal, which is not well developed, and the Middle Kittanning coal occurs from 10 to 40 feet of sandy shale or sandstone. The Middle Kittanning (Darlington) coal is the most persistent coal bed in Lawrence County. Between the Middle Kittanning and the next lower coal there is about 20 to 50 feet of shale with iron nodules. The Lower Kittanning coal, though somewhat persistent in occurrence, is decidedly irregular in quality and thickness. Below the Lower Kittanning coal is a very persistent fire clay that overlies the Kittanning sandstone member. The sandstone is generally hard and coarse and though massive in some places, is shaly in many others.

Below the Kittanning sandstone lies the Vanport (Ferriferous) limestone, the most persistent rock in the county. The limestone is usually about 15 feet thick and is commonly divided into two benches—an upper gray and a lower, thinner blue portion. It may thicken or thin within short distances. Fossils are very abundant, and the weathering of the rock produces a shriveled appearance that is very characteristic. Where the Vanport is thick it lies on the average about 75 feet below the Middle Kittanning coal, but where it is thin the interval is about 105 feet. The Lower Kittanning coal lies from 20 to 85 feet above the Vanport. In many places the Buhrstone iron ore lies directly on top of the limestone. Between the Vanport limestone and the top of the Homewood sandstone of the underlying Pottsville formation is an

interval of as much as 53 feet in which three different coal beds may occur. About 2 to 4 feet of sandy shale underlies the Vanport and separates it from the Scrubgrass coal and its fire clay. This coal is thin but is persistent over much of the county. Between the Scrubgrass and the next underlying coal a rather persistent sandstone occurs in places. About 15 to 25 feet below the Vanport the Clarion coal is generally found, and although thin it is nearly everywhere present. The Brookville coal is separated from the Clarion coal by a variable thickness of shale. The Brookville, which in many places is not present, may lie directly on the Pottsville formation or may be separated from it by fire clay and shale.

Where the sandstone members of the Allegheny formation are coarse-grained, they will generally yield moderate supplies of water to drilled wells. The water is likely to be high in iron.

Pottsville formation.—The following generalized section of the Pottsville formation in Lawrence County is compiled from data given by White [1] and DeWolf [2]:

Generalized section of Pottsville formation in Lawrence County

	Feet
Homewood sandstone member	20 — 60
Mercer shale member:	
Coal	0 — 4
Shale, with nodules of iron carbonate	0 — 20
Upper Mercer limestone	0 — 4
Upper Mercer coal	0 — 5
Upper Mercer shale	20 — 30
Lower Mercer limestone	0 — 3
Shale	0 — 18
Lower Mercer coal	0 — 3½
Lower Mercer fire clay and shale	5 — 30
Connoquenessing sandstone member:	
Upper sandstone	5 — 84
Quakertown coal, fire clay, and shale	0 — 60
Lower sandstone	5 — 75
Sharon shale member	0 — 20

DeWolf [3] describes the Homewood sandstone member as follows:

The Homewood sandstone, known to drillers as the "Forty-foot," is the top member of the Pottsville series, and is usually a massive, coarse-grained or conglomeratic bed of gray to yellow color, which measures 20 to 60 feet and averages 30 feet thick. Normally its top is a few feet below the Brookville coal, and about 160 feet below the Middle Kittanning coal. The stratum, however, is characteristically irregular in lithologic character, thickness, and in its relation to the overlying beds of the Allegheny group. It is a cliff-making bed, frequently quarried along Beaver River from Beaver Falls to Wampum and farther north in Edwards Run and Hickory Run. Along Connoquenessing Creek, however, and east of Beaver River between Chewtown and New Castle the horizon of the Homewood is filled with shale.

Where the Homewood is massive it is usually 30 to 35 feet thick. In numerous exposures the sandstone contains quartz pebbles as large as acorns, though commonly smaller. The pebbly portions may occur in any part of the bed. Cross-bedding is a rather common feature of the sandstone. Directly beneath the Homewood sandstone or separated from it by as much as 5 feet of shale is the Tionesta coal. This coal, though everywhere very impure, is rather persistent in the county. The iron shales that occur below the Homewood are not everywhere

[1] White, I C., op. cit., pp. 51-70.
[2] DeWolf, F. W., op. cit., pp. 47-57.
[3] Idem, p. 48.

present, and in such places the Homewood rests directly on the Upper Mercer limestone or in places even cuts out the limestone and some of the lower strata. The Upper and Lower Mercer limestones lie 20 to 35 feet apart. They are very similar in most respects, dark blue, fossiliferous, and hard. The upper limestone is not persistent, but the lower is one of the most persistent beds in the county. The Upper and Lower Mercer coals are both very persistent in Lawrence County. The upper coal occurs directly beneath the Upper Mercer limestone, which in some places also has a coal bed directly above it, but where the limestone thins out the two coals come together and form one bed. The Lower Mercer coal may occur directly below the Lower Mercer limestone or may be separated from it by as much as 18 feet of shale. Both the upper and lower coals are impure and of very little value except as persistent horizon markers. Below both the upper and lower coals occurs as much as 30 feet of shale, near the bottom of which iron ore is present. The upper iron ore bears the same relation to the Lower Mercer limestone as the Vanport limestone bears to its iron ore.

The Connoquenessing sandstone member has a threefold division in many parts of Lawrence County, the upper and lower sandstones being separated by as much as 60 feet of shale. The following description of the Connoquenessing sandstone member is taken from DeWolf [4]:

> The Upper Connoquenessing sandstone, or Sixty-foot, is usually the second massive member of the Pottsville series, occurring next below the Mercer formation and about 225 feet below the Middle Kittanning coal. It loses its massive character in some places, as at Mahoningtown; in others, where the Mercer formation is absent, it appears to be continuous with the Homewood sandstone, as seen at the type locality of the latter bed; and in other places it is probably continuous with the Lower Connoquenessing sandstone. Where exposed as a distinct sandstone it ranges from 5 to 84 feet in thickness, averaging about 40 feet. It is a massive bed, usually suitable for quarrying, but in many places shows variable bedding features. The texture is coarse but shows all phases from conglomerate to sandy shale. The color varies from white to yellowish brown * * *.
>
> The Quakertown coal lies beneath the horizon of the Upper Connoquenessing sandstone and about 265 feet below the Middle Kittanning coal. It seems to be absent in many places and is practically never of minable thickness, ranging up to 22 inches. Below the coal occurs fire clay and shale which is characteristically ferruginous like the Mercer shales. It is 60 feet thick at Homewood but more commonly measures 30 feet or less.
>
> This bed was named by I. C. White from the occurrence near Quakertown, Pa., about 4 miles north of Bessemer. It persists as a thin coal or bituminous shale in much of Lawrence County and is known along Mahoning River, Beaver River, and Connoquenessing Creek * * *.
>
> The Lower Connoquenessing sandstone is the lowest massive bed exposed in this region. It is separated from the Upper Connoquenessing by the Quakertown coal and shale horizon and where seen lies about 285 feet below the Middle Kittanning coal. It is a coarse-grained white rock, usually massive or thick-bedded; in places, however, it may be conglomeratic or shaly. Along Connoquenessing Creek, where its name was given to the bed by I. C. White, the sandstone is brown and ferruginous. The exposures of this bed range from 5 to 75 feet in thickness, averaging 40 feet where the development is not abnormal.
>
> This is probably the so-called "Big Injun" sand of the Purdy pool, and of some other wells.

The total thickness of the Connoquenessing sandstone member in Lawrence County ranges from 120 to 150 feet.

[4] DeWolf, F. W., op. cit., pp. 53-57.

Below the Connoquenessing sandstone occurs as much as 20 feet of shale, near the base of which the Sharon coal is found. Very little is known of this coal in Lawrence County. Near New Castle the Sharon shale is absent, the underlying Cuyahoga shale, with its characteristic fossils, extending up to the base of the Connoquenessing. The Sharon conglomerate, which marks the base of the Pennsylvanian series in the region to the north, is apparently absent or poorly developed in Lawrence County.

The sandstone members of the Pottsville formation generally yield moderate to excellent supplies of water to drilled wells, although where the sandstone is thin-bedded or shaly only small supplies are generally obtained. The water is likely to be high in iron.

Pocono group.—Only about 40 feet of the Pocono group is exposed in Lawrence County. For a description of the group the reader is referred to Mercer County.

Structure.—The rocks of Lawrence County, though seeming to be horizontal, actually dip a little west of south at a rate of about 10 to 15 feet to the mile. There are irregularities and reversals in this dip, but they are slight and only of local extent.

GENERAL GROUND-WATER CONDITIONS

Lawrence County is moderately well supplied with ground water for domestic needs and for the smaller industrial and municipal uses. Drilled wells are mostly used, and although a few dug wells are still in use they are gradually being replaced by drilled wells because they are not reliable sources of water during the dry season. Small springs are numerous and where favorably located are used for domestic supplies as well as for the smaller municipal supplies. In many parts of the county water high in iron is encountered in wells that penetrate coal-bearing rocks, and in these localities the main problem is that of obtaining water low in iron or treating the already developed supplies for the removal of iron.

The chief water-producing rocks in the county are the sand and gravel of the glacial drift and the sandstones of the Allegheny and Pottsville formations. In general the glacial gravel occurs in sufficient thickness to be a good producer of ground water only in the major valleys of the county. The sandstones of the Allegheny formation, where massive, are usually good producers of water, but as the massive characteristic is not persistent for great distances these sandstones cannot be relied upon as sources of water in all parts of the county. The Homewood and Connoquenessing sandstones of the Pottsville formation are more persistently massive than the sandstones of the Allegheny formation, and they are therefore more reliable as water bearing rocks than the sandstone in the Allegheny. However, in places where the Homewood and Connoquenessing are replaced by shale or consist of shaly sandstone, very little water can be obtained from them.

The structure of the rocks in Lawrence County is such that water under artesian pressure is encountered in some places, though it may not be sufficient to cause the water to flow. Wells 267, 271, 273, 283, 285, and 288 encountered water that was under artesian pressure, but only in wells 267 and 288 was the pressure great enough to produce a flow at the surface. No very striking anticlines and synclines are

present in Lawrence County, and because the structure has not been worked out in detail for the county as a whole the locations at which artesian wells can be expected cannot be predicted.

It is reported that in the Bessemer region a brown water-bearing sandstone about 35 feet thick generally occurs about 30 feet above the Vanport limestone. This is probably the Kittanning sandstone. It is also reported that about 25 feet below the Vanport limestone a white water-bearing sandstone is encountered. The Mountain sand of this area is said to lie from 50 to 100 feet below the Vanport limestone. It appears that both the Homewood and Connoquenessing sandstones are locally known as the Mountain sand in this region. In the valley walls just south of Wampum a spring that flows about 3 gallons a minute issues from a shale that lies about 90 to 100 feet below the Vanport limestone. The water is piped to the town at two separate watering troughs and supplies the needs of a number of the inhabitants of the town. In parts of the county salt water is encountered in wells 300 feet or more in depth. (See wells 270, 280, 286, 288 and 291.) There are several old oil and gas wells in the county which were never properly plugged when abandoned, and it appears that salt water from some of these old wells is leaking into the shallower depths and contaminating supplies that would otherwise be good fresh water. Well 286 appears to present an example of this contamination.

QUALITY OF WATER

Analyses of waters from Lawrence County are tabulated on pages preceding the county descriptions. Here, as in many other parts of northwestern Pennsylvania, waters from wells that end in sandstone or coal-bearing rocks may be expected to contain moderate to large amounts of iron. Waters derived from the sand and gravel of the glacial drift are likely to be hard. In parts of Lawrence County deep drilling is not advisable because of the likelihood of encountering salt water. In some parts of the county old oil and gas wells that were never properly plugged are leaking salt water into beds that lie at relatively shallow depths. All wells—whether water, oil, or gas wells—should be tightly plugged when they are abandoned, so that near by wells will not become contaminated or polluted.

PUBLIC SUPPLIES

As shown in the next table only four of the eight towns in Lawrence County that have public supplies derive their water from wells or springs, and these are the smaller towns, New Castle and Ellwood City depending on surface water for their municipal supplies. Wampum and Volant each derive their supply from one drilled well in sandstone. Pulaski is supplied by a number of springs less than half a mile west of the village, on the hillside. The water probably issues from a sandstone of the Pottsville formation. New Wilmington obtains its water from 4 drilled wells and 6 springs. All these towns appear to have sufficient water to meet their needs for some time to come, with possibly the exception of New Wilmington, but it is probable that additional supplies can be obtained by drilling new wells as the demand for water becomes more pressing.

Public water supplies in Lawrence County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Ellwood City	12,323	Ellwood Water Co.	Slippery Rock Creek			Direct [a]	6,000,000	2,000,000		Chlorine gas, alum, lime, filter, sedimentation.
New Castle	48,674	City of New Castle Water Co.	Shenango River			Direct, gravity [a]	6,335,000	4,500,000		do.
New Wilmington [b,c]	907	New Wilmington Water Co.	4 drilled wells, 6 springs	Lower part of Pottsville formation	Deep-well pumps	Gravity	30,000	50,000	80—	Chlorine gas.
Pulaski		Pulaski Water Co.	Springs			do.	42,000	2,300		None
South New Castle	1,038	City of New Castle Water Co.								
Volant [c]	186	Municipal	1 drilled well	Connoquenessing sandstone	Deep-well pump	Gravity	20,000	9,000		None
Wampum [c]	883	do.	do.	Pottsville formation	do.	Direct [a]	450,000	35,000	98—	do.
West Pittsburgh		West Pittsburgh Water Co.	Beaver River			do.	141,000	95,000		Soda, hypochlorite of lime, sedimentation, filter.

[a] Excess to reservoir.
[b] See analysis.
[c] See record of wells in following table.

Drilled wells in Lawrence County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
267	2 miles southeast of New Bedford [b]	----------	----------	---------	95±	-----	-------	Sandstone	----------	------	Flow	Domestic	Flows at 3 feet above surface.
268	½ mile northeast of Pulaski	Pulaski Fair Grounds	Flood plain --	840+	140	-----	-------	Gravel	Glacial drift ----	140	-----	Abandoned Domestic	Well does not reach bedrock.
269	½ mile east of Pulaski	----------	Hillside -	900+	110	-----	-------	Sandstone	Pocono group --	------	50		
270	Pulaski -------	Herman Knox --	do.	840+	320	-----	-------	do.	do.	------	8	do.	So-called "mineral well"; analysis shows high NaCl content.
271	¼ mile south of New Wilmington	New Wilmington Water Co.	do.	1,100+	583	-----	30±	do.	Lower part of Pottsville (?) -	17	18±	Abandoned	At about 60 gallons a minute well pumped dry in 20 minutes.
272	do.	New Wilmington Water Co., well 4	do.	1,100+	250	6½	190±	do.	do.	17	------	Public supply	See analysis.
273	do.	New Wilmington Water Co., well 5	do.	1,100+	297	-----	200±	do.	do.	20	154	do.	Water also encountered at a depth of 35 feet in sandstone. See analysis.
274	do.	New Wilmington Water Co.	do.	1,100±	258	-----	-------	----------	do.	17±	------	do.	----------
275	do.	do.	do.	1,100±	300	-----	-------	----------	do.	17±	------	do.	Pumped about 40 gallons a minute.
276	Volant -------	Volant Borough	do.	1,120±	224	6¼	-------	Sandstone	Connoquenessing ----	108	------	do.	Blue till 108 feet, sandstone 116 feet adequate supply of water.
277	do. [b]	----------	----------	---------	90	-----	-------	Gravel	Glacial drift ----	------	27±	Domestic	Well does not reach bedrock.
278	Plain Grove --	----------	Flat ----	1,180	86	-----	-------	do.	do.	86	35	do.	Blue silt 85 feet, gravel 1 foot; small drawdown by bailing about 75 gallons a minute.
279	1 mile northwest of Coaltown	J. H. Conner --	Hillside -	1,080+	60	-----	-------	Shale	Middle of Allegheny	------	21	do.	Coal 4 feet thick at depth of 20 feet.
280	1 mile west of Edinburg	----------	do.	900+	2,680	-----	-------	----------	----------	------	------	None	Oil well in which all fresh water was shut off at 225 feet; salt water at 510 feet.

Drilled wells in Lawrence County (Continued)

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
281	Bessemer[b]	Manava	Flat		72			Shale	Lower part of Allegheny		40	do.	Surface 40 feet, shale 32 feet.
282	½ mile southwest of Mahoningtown	City of New Castle disposal plant	Flood plain	770	68					30	20	Domestic	Gravel and sand 30 feet, shale of Pottsville formation 38 feet.
283	do.	do.	do.	770	16	1¼	15	Gravel	Recent alluvium	16	10	do.	Driven well. See analysis.
284	Mahoningtown[b]		Terrace		150			Sand and gravel	do.	150		do.	Well does not reach bedrock.
285	Shenango Township[b]	Shenango Township School			131	6¼	80±	Sandstone			70	do.	Yellow clay 20 feet, yellow sandstone 40 feet, shale 13 feet, white sandstone 58 feet.
286	New Castle	Hunter's Laundry	Flood plain	800+	185	4½	20	Gravel	Recent alluvium	185	20	Industrial	Gravel 20 feet, "quicksand" 165 feet, well ends on bedrock; water salty, reported to come from old gas well near by which was not plugged.
287	5 miles east of New Castle	Buffalo, Rochester & Pittsburgh R. R.	Flat	1,090	90				Glacial drift	90		Domestic	Well does not reach bedrock.
288	do.	Big Run Oil & Gas Co.	Valley	1,055			120	do. (?)	do.		Flow		Old oil well; 120 feet to bedrock; water at 120 feet flowed, reported to be sulphurous; water in sandstone at 130 feet flowed, reported to be sulphurous; salt water at 670 feet.
289	¼ mile north of Princeton	Princeton Schoolhouse	Upland flat	1,310±	134	6¼	100+	Limestone (?)	Vanport	34	100	Domestic	Glacial till 34 feet, shale 66 feet, Vanport limestone 18 feet, shale 16 feet. See analysis.
290	3 miles southeast of Princeton	Shaffer well	Hillside		1,411								Old oil well cased at 247 feet, which shut off all fresh water.[c]

291	3 miles northeast of Wurtemberg	Chew well	do.		790		200±	Sandstone	Connoquenessing				Old oil well; fresh water in hard white sandstone from 169 to 236 feet, salt water from 327 to 352 feet. Another well near by encountered fresh water at 117 feet.[d]
292	Ellwood City	Schuler's Butcher Shop	Rock terrace	900+	62			do.	do.	21	22	Domestic	Yellow clay 21 feet, sandstone 41 feet.
293	Chewton	Peter Guy	do.	900+	90			do.	Upper part of Pottsville	80	60	do.	Gravel 80 feet, white sandstone 10 feet. See analysis.
294	Wampum	Wampum Borough	Flood plain	760+	89	8		do.	Pottsville	30	22	Public supply	Gravel 30 feet, Pottsville sandstone and shale 59 feet; 12-foot drawdown pumping 125 gallons a minute for 72 hours; water reported to be very hard.
295	do.[b]	Stegiitz	Valley		80					60	40	Domestic	Gravel 60 feet, Connoquenessing sandstone 20 feet.
296	Enon Valley	Harry Good	do.	980+	66	4½		Gravel	Glacial drift	66	30	do.	Well does not reach bedrock. See ananlysis.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] Pennsylvania Second Geol. Survey, Rept. Q², p. 154, 1879.
[d] Idem, p. 89.

MERCER COUNTY

GENERAL FEATURES

Mercer County lies near the middle of the western tier of counties along the Ohio State line. It is almost square in outline and has an area of 700 square miles. In 1930, according to the United States Census, it had a population of 99,246. Three of the 20 largest cities and boroughs in the area described in this report are in Mercer County, —Sharon with 25,908, Farrell with 14,359, and Greenville with 8,628 inhabitants. In 1930 the county had 133 manufacturing establishments.

The western part of Mercer County is drained by Shenango River and its tributaries, the northeastern part by tributaries of French Creek, and the southeastern part by Neshannock and Wolf creeks. Most of the major streams flow in valleys that are deeply filled with glacial drift. Along many of these valleys swamps are numerous, particularly in the eastern part of the county. The region is one of moderate slopes, though many parts form gently rolling surfaces. Flat areas are rather numerous, both along the valleys and on the uplands. Near the eastern county line numerous hills are more than 1,600 feet above sea level, but along the Ohio State line the highest areas are less than 1,300 feet above sea level. The highest points in the county occur about 1 mile northwest of Henderson, where four small knobs rise more than 1,620 feet above sea level. The lowest point in the county is in the valley of Shenango River where it crosses the south county line, less than 820 feet above sea level. The maximum relief in Mercer County is therefore about 800 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

Essentially all of Mercer County was covered by ice during the glacial epoch. In the southeastern part of the county the glacial drift is relatively thick. Although there is some evidence from well records in the southeastern part of the county that old valleys have been completely filled with glacial drift, the records are not numerous enough to establish with certainty the course of any of these old valleys. In places, however, the records seem to indicate that a relatively thick layer of glacial drift was deposited on an irregular bedrock surface. Most of the larger valleys in the county are deeply filled with glacial outwash. Plate 4 shows the extent and thickness of this valley filling. The following log shows the character of the material in a well near West Middlesex, which passes through a considerable thickness of glacial outwash:

Log of well (266) ending in lower part of Pocono (?) group 1 mile southeast of West Middlesex

	Thickness (feet)	Depth (feet)
Sand, gravel, and loam	20	20
"Quicksand", soft, blue-gray	145	165
Sand and gravel	35	200
"Quicksand"	15	215
Sand and gravel	14	229
Sandstone (Mountain sand)	78	307

The glacial outwash generally yields good to excellent supplies of water to drilled wells that are finished with screens and properly developed. The water is likely to be somewhat hard.

ROCK FORMATIONS [5]

The rock formations of Mercer County are in most localities covered with thick deposits of glacial drift. However, along many of the valleys the bedrock is exposed, and by a careful study of these exposures together with well records the sequence of rocks becomes evident. The rock formations extend from about the Freeport sandstone member of the Allegheny formation down to and including a part of the Orangeville shale member of the Cuyahoga formation. Most of the county is underlain by the Pottsville formation. In the southeast half of the county there are a number of outliers of the Allegheny formation. In the northwestern part of the county the bedrock is mostly Pocono, with outliers of the Pottsville formation. Along parts of most of the major valleys the streams have cut down to the Pocono. The areal distribution of the formation is shown on plate 5.

Allegheny formation.—The following compiled section of the Allegheny formation as exposed along Wolf Creek is taken from I. C. White.

Section of Allegheny formation on Wolf Creek, Mercer County

	Ft.	*In.*
Concealed (probably includes a part of the Freeport sandstone)	75	
Shale, dark	5	
Darlington coal	3	2
Fire clay	5	
Shale, sandy	40	
Lower Kittanning coal	2	
Concealed	45	
Vanport limestone	15	
Shale	3	
Scrubgrass coal	1	
Shale and standstone	25-40	
Brookville coal	4	8
Fire clay and sandy shale	5-15	
	253	10

The area underlain by the upper part of this section is small, and a description of these higher rocks is given under Lawrence County.

The Vanport (Ferriferous) limestone of the Allegheny formation is found only in isolated patches in the southeast group of townships. A high knob near Henderson, in Worth Township, is the most northerly occurrence of the limestone. Where present in this county, the Vanport shows the same characteristics as in Lawrence County. Beneath the Vanport and separating it from the Scrubgrass coal occurs 1 to 5 feet of gray or black shale. The Scrubgrass coal, generally less than 1 foot thick, is present under all exposures of the Vanport in Mercer County. Between the Scrubgrass coal and the next underlying coal (Brookville) there is an interval of as much as 50 feet

[5] The following descriptions are taken mainly from I. C. White (Pennsylvania Second Geol. Survey Rept. Q³, 1880).

which in some places is occupied mostly by shale but in others is occupied by massive sandstone 20 to 30 feet thick. This interval includes the horizon of the Clarion coal, but nowhere in Mercer County has this coal been definitely recognized. Between the Brookville coal, the most valuable coal bed in Mercer County, and the Homewood sandstone member of the underlying Pottsville formation occurs 5 to 15 feet of fire clay and sandy shale. Because of the small areal extent of the Allegheny formation in this county it is of little value as a source of water.

Pottsville formation.—White gives the following generalized section of the Pottsville formation in Mercer County:

Section of Pottsville formation in Mercer County

	Feet
Homewood sandstone	60
Mercer shale member:	
Shale	0 — 10
Iron ore	0 — 2
Upper limestone	0 — 2½
Upper coal	0 — 2½
Shale	25
Iron ore	0 — 2
Lower limestone	2½
Shale	0 — 10
Lower coal	0 — 4
Shale	10
Iron ore	0 — 1
Shale	5
Connoquenessing sandstone member:	
Upper sandstone	40
Shale and iron ore	10
Quakertown coal	0 — 2
Shale	40
Lower sandstone	30
Sharon shale member:	
Shale and iron ore	30
Sharon coal	0 — 4
Fire clay and shale	5
Sharon conglomerate	20

The total thickness as given by this generalized section is somewhat too great because direct measurements of the formation show it to be about 250 feet thick. The Homewood sandstone is very persistent in Mercer County and is generally a coarse, massive rock 30 to 70 feet thick. In places it is conglomeratic. Commonly it is whitish gray, but in many places it is buff. It may be cemented tightly into a hard, compact rock or may be soft and friable.

Between the Homewood and Connoquenessing sandstones is the Mercer shale member, which consists of shale, limestone, and coal, as shown in the above section.

The Connoquenessing sandstone member in this county consists of an upper and a lower sandstone separated by 30 to 50 feet of shale, coal, and iron ore. In many localities the upper sandstone is massive and conglomeratic near the top and has been used for building stone. In other places sandstone seems to be absent and the horizon entirely occupied by shale. The sandstone is usually light gray and moderately coarse-grained. The 30- to 50-foot interval between the upper and lower sandstones is occupied by sandy shale locally containing nodular iron ore. Near the top of this interval is the Quakertown coal, which is persistent in Mercer County and has been mined at numerous places, though it is rather impure. The lower sandstone is similar in a general way to the upper one but appears to be more variable in thickness. It is entirely absent in some localities but in others shows a thickness of 90 feet of hard, massive sandstone. Cross-bedding is rather prominent in some exposures.

The average distance between the base of the Connoquenessing sandstone and the Sharon coal is about 30 feet, though in some places it is as great as 70 feet and in other places the sandstone rests directly on the coal or even cuts it out and rests on lower beds. The interval is generally occupied by dark or bluish-gray shale, although sandy layers and ironstone concretions are also locally present. Two direct measurements made by White in Mercer County of the distance between the top of the Homewood sandstone and the Sharon coal show the interval to be 225 and 235 feet.

The Sharon conglomerate averages about 20 feet in thickness in Mercer County. At the town of Sharon, on the Ohio State line (type locality), it lies about 5 feet below the Sharon coal and in the upper part consists of coarse white sandstone. The lower part is made up of a mass of rounded pebbles as large as hickory nuts poorly cemented in coarse bluish-gray sand. The nonconglomeratic phases of the rock were extensively used in the locks of the old Beaver & Erie Canal. In parts of the county the rock appears to grade into a thin-bedded sandstone, and in the vicinity of Greenville it has supplied a great amount of flagstones. The following chemical analyses were made on samples of the Sharon sandstone collected near Greenville:

Analyses of Sharon sandstone from quarry 2 miles southeast of Greenville, Pa., owned by White Rock Silica Co.

(Analyses by Pittsburgh Testing Laboratories)

	Sample 1 (top unwashed)	Sample 2 (bottom unwashed)
Alumina	0.26	1.65
Iron oxide	.21	.57
Titanium oxide	.25	.15
Calcium oxide	.13	.18
Magnesium oxide	.10	.47
Alkalies	.05	.80
Loss on ignition	.50	1.04
Silica (by difference)	98.50	95.14

The following log shows the character of the bed in a well that passes through the Pottsville formation:

Log of well (239) ending in upper part of Pocono group, in Grove City, Pa.

	Thickness (feet)	Depth (feet)
Surface	35	35
Sandstone (Homewood)	63	98
Sandstone, shaly	17	115
"Slate"	120	235
Sandstone (Mountain sand)	69	304
"Slate"	6	310

The position of the base of the Pottsville is not clear in this log, because the contact of the Pottsville and the underlying Pocono lies in the 195 feet of sandy rocks near the bottom of the well.

The three sandstone members of the Pottsville formation are all good producers of water, although only small quantities of water will generally be obtained where the rocks are thin-bedded or shaly. The water is likely to be high in iron and may be somewhat highly mineralized and hard.

Pocono group.—The following generalized section of the lowest rocks exposed in Mercer County is compiled from data given by White:

Section of beds of Pocono group in Mercer County

	Feet
Burgoon sandstone:	
Sandy shale and thin-bedded sandstone (Shenango shale of I. C. White)	45
Sandstone, massive with many iron nodules (Shenango sandstone of I. C. White)	15
Cuyahoga formation:	
Meadville shale (bluish gray)	90
Sharpsville sandstone (thin-bedded)	55
Orangeville shale	75±

The upper shaly member of the Burgoon sandstone is nowhere more than 50 feet thick. It consists of thin-bedded sandstone separated by layers of shale. The underlying massive sandstone member is very persistent in Mercer County as a massive, fossiliferous rock, everywhere containing large numbers of ironstone concretions. It is usually coarse-grained, white to brown, and loosely cemented. In places, however, it is very dense, owing to the complete cementation of the sand grains. It ranges in thickness from about 3 to 25 feet.

In his report on Mercer County White[6] used the name "Crawford shales" for the 90 feet of shale lying below the Burgoon sandstone and above the Sharpsville sandstone. He later made the name "Crawford shales" synonymous with the Cuyahoga formation, which he called "Meadville group."[7] What he originally called "Crawford shales" in Mercer County is therefore equivalent to the Meadville shale member of the Cuyahoga formation of present nomenclature. In Mercer County the shale is quite clayey and generally bluish gray.

[6] White, I. C., Pennsylvania Second Geol. Survey Rept. Q[2], p. 61, 1880.
[7] White, I. C., Pennsylvania Second Geol. Survey Rept. Q[4], p. 68, 1881.

The Sharpsville sandstone is a thin-bedded rock in which the individual layers of sandstone and shale are generally 1 to 2 feet thick, though in places they reach 5 feet. The shale layers are commonly thinner than the sandstone layers. The sandstone is generally dark gray to brown and fine-grained. The thickness of the member is about 50 to 60 feet. The Orangeville shale is the lowest rock exposed in Mercer County. On fresh surfaces it is blue, but the weathered faces are reddish brown. Sandy layers are present, but they are generally less than 6 inches thick. In places many ironstone concretions occur.

The sandstones of the Pocono group, particularly the lower part of the Burgoon sandstone, generally yield good supplies of water to drilled wells. The water may be highly mineralized and moderately high in iron and in some places, if encountered at considerable depths, may be somewhat salty.

Structure.—The rocks of Mercer County lie nearly flat, the dip to the south of about 15 feet to the mile being so slight that only careful leveling reveals it. In places there are slight reversals of dip, but such conditions are local.

GENERAL GROUND-WATER CONDITIONS

Mercer County is well supplied with ground water for domestic uses and for smaller industrial and municipal requirements. With the increasing demands of the present users of ground water additional wells can be put down that will furnish adequate quantities of water for some time to come. Small springs are numerous and are utilized in many areas. Most of the wells in the county are drilled, and the dug wells that are being used are gradually becoming inadequate and are being replaced by drilled wells. Considerable difficulty is encountered with water high in iron in some areas where there is an adequate quantity of water.

The sand and gravel of the glacial drift and the sandstones of the Pottsville formation and the Pocono group are by far the most productive water-bearing rocks in the county. Most of the satisfactory wells that end in the sand and gravel of the glacial drift are located along the major valleys that are shown on plate 4. The sandstones which can usually be relied upon to yield moderate supplies of water are the Homewood and Connoquenessing of the Pottsville formation and the lower part of the Burgoon sandstone of the Pocono group. All these sandstones are rather persistent throughout the county. However, in places they are more or less shaly or so tightly cemented that they contain very little water. Not uncommonly the water in all of them is found to be high in iron, in some places so high that the water is unfit for ordinary uses. Although the rocks of Mercer County lie essentially flat, there is a regional dip to the south as well as other minor flexures in the rocks, so that not uncommonly wells drilled in this county encounter water under artesian pressure though in most places the pressure is not great enough to cause the water to flow at the surface. Some flowing wells have been obtained in the glacial drift, as for example well 211. Other wells that encountered water under artesian pressure are wells 181, 187, 191, 213, 234, 235, 239, 243, 244, 245, 248, 265, and 266. Although some new wells will undoubtedly

strike artesian water, there is not much likelihood of obtaining many flowing wells.

QUALITY OF WATER

Analyses of waters from Mercer County are tabulated on earlier pages. Many of the waters are high in iron, particularly those derived from sandstone and coal-bearing rocks. Samples 191 and 266, however, did not contain much iron. Deep drilling is not advisable in many parts of the county, because of the likelihood of encountering water high in sodium chloride. This is particularly true in the deeper valleys, for in these localities the deeper rocks are penetrated at shallower depths than in the upland regions. Analyses 265 and 266 were made on waters from wells in one of the deepest valleys, and both of them show larger quantities of chloride than any other analyses in the table. However, the chief problem in the county is that of obtaining water low in iron or of removing iron from already developed supplies. According to reports, most of the waters high in iron are obtained from the sandstone and shale of the Pottsville and Allegheny formations, the underlying Pocono group yielding water considerably lower in iron.

PUBLIC SUPPLIES

As shown in the following table, several towns in Mercer County derive their public supplies from ground-water sources. Grove City and Sharpsville are the two largest towns in the county supplied from ground water. It is reported that Sharpsville will have to enlarge its present supply in order to meet future needs, but this can perhaps be accomplished by drilling additional wells. Grove City appears to be well supplied for some time to come, and the local conditions seem to indicate that there is good opportunity of developing additional supplies by drilling new wells.

Public water supplies in Mercer County

Town	Population 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Farrell	14,359	Shenango Valley Water Co								
Greenville	8,628	Municipal	Tributary of Little Shenango River			Gravity	85,000	1,000,000	75—	Chlorine gas, alum, lime, sedimentation, filter.
Grove City [a]	6,150	do.	2 drilled wells	Upper part of Pocono group	Air	Direct [b]	370,000	729,000—	55—	Alum, lime, soda ash, filter.
Jamestown	710	Jamestown Water Co.	3 drilled wells, 2 springs		do.	Gravity	600,000	100,000	57+	None
Mercer	2,125	Mercer Water Co.	Otter Creek			do.	73,000	250,000	160—	Chlorine gas, alum, sedimentation, filter.
Sandy Lake	679	M. C. Potter	3 springs			do.	67,500	12,000	75	None
Sharon	25,908	Shenango Valley Water Co.	Shenango River			Direct [b]	2,100,000	4,000,000	120+	Chlorine gas, alum, lime, sedimentation, filter.
Sharpsville [a]	5,194	Municipal	4 drilled wells, 1 dug well	Pocono group and glacial drift	Air	do.	381,000	1,000,000	115—	Hypochlorite of lime.
Stoneboro	1,189	do.	6 springs			Gravity	225,000		55+	None
West Middlesex [a]	1,181	do.	2 drilled wells	Lower part of Pocono group (?)	Deep-well pumps	Direct [b]	228,000	75,000	85—	do.
Wheatland	1,518	Shenango Valley Water Co.								

[a] See analysis and record of wells.
[b] Excess to reservoir.

Drilled wells in Mercer County

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[d]	Remarks
180	2 miles southeast of Jamestown	Frank Stewart	Hillside	1,080	240	4½	-------	Sandstone (?)	Pocono (?)	-----	40	D.	----------
181	do.	Donnor	do.	1,020	190	4½	151	do. (?)	do.	-----	80±	do.	Hard gravel sand and clay 151 feet, white sandstone (?) 39 feet.
182	Greenville[b]	G. C. Swartzbeck	Flat	---------	75	4½	-------	do.	----------	21	25±	do.	Till 21 feet, gray sandstone 54 feet.
183	do.	Bessemer & Lake Erie R. R.	Valley	940	240	-----	-------	do.	Conewango (?)	-----	------	Ind.	Drawdown of about 23 feet pumping about 40 gallons a minute.
184	do.	do.	do.	940	195	6	135	do.	Pocono (?)	-----	------	do.	No record 76 feet, "slate" 59 feet, white sandstone 60 feet; drawdown of about 23 feet pumping about 40 gallons a minute.
185	do.[b]	do.	do.	---------	210	12	-------	do.	do.	100	------	do.	Bedrock encountered at 87 feet. See analysis.
186	1 mile east of Greenville	J. W. Young	Slope	1,120	120	4½	-------	Shale	Pocono	51	85±	D.	"Hardpan" and blue clay 51 feet, shale 69 feet.
187	2 miles southeast of Greenville	Greenville County Club	Upland flat	1,120	354	10	308	Sandstone	Lower part of Pocono	20	94	do.	Surface 7 feet, sandstone 43 feet, "slate" 258 feet, white sandstone 46 feet; water encountered in shale at 60 feet but was lost in a "crevice" at 94 feet; no more water encountered down to 308 feet; at time of completion well tested 183 gallons a minute. See analysis.
188	do.	L. P. Kellar	Hillside	1,160	64	6	-------	do.	Upper part of Pocono	-----	8	do.	Surface 8 feet, sandstone 56 feet; drawdown of 2 feet pumping with hand pump.
189	do.	Mrs. J. Lleblich Silica Co.	Upland flat	1,180	60	4½	-------	do.	do.	21	23	do.	Till 21 feet, sandstone 39 feet.
190	3 miles southeast of Greenville	White Rock	Hillside	1,200±	401	-----	-------	----------	Pocono	-----	------	Ind.	Water encountered at 160 feet and numerous deeper horizons; well pumped about 12 gallons a minute
191	Sharpsville	Sharpsville Borough	Valley flat	880	190	8	140	----------	do.	59	30	PS	Sand and fine gravel 56 feet, blue silt 1 foot, "slate" and sandstone 83 feet, white sandstone 50 feet; 4 similar wells 75 feet apart. See analysis.
192	do.	do.	do.	880	20	-----	-------	Gravel	Glacial drift	20	12	do.	Dug well 25 feet in diameter.

193	do.	Feed mill	do.	880	90						9	D.	
194	Clarksville	G. F. Osborn	do.	900	87			Sandstone	Pocono			do.	
195	5 miles northeast of Sharpsville	Simpkins Barbeque	Upland flat	1,120	132			Shale	do.		20±	do.	
196	New Hamburg	Church	Valley	960	245±	4½		Sandstone	Conewango (?)	100±	60+	do.	100+ feet to bedrock.
197	½ mile from Kremis Railroad station [b]		Flat				410	do.				none	Old oil well; fresh water in sandstone between 410 and 490 feet.
198	Kremis	Bessemer & Lake Erie R.R.	do.	1,160	250	10			Pocono	120		Ind.	Bedrock encountered at 120 feet; some water in gravel at 100 feet; more water in sandstone at about 130 feet and at several deeper horizons; small drawdown pumping about 166 gallons a minute.
199	5 miles southeast of Greenville	George Graeott	do.	1,160	120	4½		Sandstone	Upper part of Pocono		65±	D.	Yellow clay 4 feet, sandstone 5 feet, bituminous "slate" 81 feet, sandstone 39 feet.
200	Fredonia [b]	Mary Smith			23	4½		do.	Lower part Pottsville	8	4	do.	Till 8 feet, yellow sandstone 6 feet, gray sandstone 9 feet.
201	Fairview	James Orr	Flat	1,280	55	4½		do.	do.	28	18	do.	Clay and sand 28 feet, gray sandstone 27 feet.
202	do.	Miss Bell Stewart	do.	1,280	68	4½		do.	do.	22	20	do.	Till, sand and gravel 22 feet, sandstone 46 feet. See analysis.
203	½ mile north of Fairview	E. Fenstmaeher	Valley	1,260	60	4½		do.	do.	32	32	do.	Till 32 feet, sandstone 28 feet.
204	3 miles northeast of Fairview	John Slater	Flat	1,340	70	4½		do.	Pottsville	42	17	do.	Till, gravel and sand 42 feet, thin-bedded sandstone 28 feet.
205	2½ miles northeast of Fairview		do.	1,320	100			Gravel	Glacial drift	100		do.	Well does not reach bedrock.
206	2 miles northeast of Fairview	David Thorpe	Hillside	1,360	68	4½		Shale	Pottsville	54	25±	do.	Till, sand, and gravel 54 feet, "slate" 14 feet.
207	2 miles north of Fairview	O. C. Neal	Flat	1,360	85	5⅝		Sandstone	do.	22	25	do.	Till 22 feet, sandstone 63 feet.
208	2½ miles north of Fairview	E. E. Marsteller	do.	1,360	48	4½		do.	do.	30	12	do.	Till 30 feet, gray sandstone 18 feet.
209	do.	do.	do.	1,360	38	5⅝		do.	do.	15	17±	do.	Clay and sand 15 feet, sandstone 23 feet; water reported to be high in iron.
210	do.	do.	do.	1,370	60	4½		do.	do.	12	18±	do.	Till 12 feet, sandstone 48 feet.
211	3½ miles southwest of Clarks Mills	John Hagerty	do.	1,340	22	4½		Gravel	Glacial drift	22	Flows	do.	Reported to flow about 13 gallons a minute with static head 4 feet above ground level; water reported to be high in iron; casing rests on sandstone.
212	2 miles southwest of Clarks Mills	E. E. Etter	do.	1,360	56	4½		Sandstone	Pottsville	44	18	do.	Till 44 feet, gray sandstone 12 feet.

Drilled wells in Mercer County (Continued)

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [d]	Remarks
213	2 miles southwest of Clarks Mills	J. C. McDowell	Flat	1,320	72	4¼	50	Sandstone	Lower part of Pottsville	42	13	D.	Clay 22 feet, sand and gravel (some water) 20 feet, "hard" rock 2 feet, fire clay 7 feet, gray coarse-grained sandstone 21 feet.
214	3½ miles northeast of Fairview		Valley	1,260	72			Gravel	Glacial drift	72			Well does not reach bedrock.
215	½ mile southeast of Clarks Mills		do.	1,160	275			do.	do.	275			do.
216	1½ miles west of Clarks Mills	Yeggar & Bentley	Hillside	1,240	65	5⅝		Sandstone	Upper part of Pocono	37	25±	D.	Till 37 feet, gray sandstone 28 feet.
217	do.	W. H. Simmons	Valley	1,140	61	4¼		do.	do.	37	43	do.	Till 37 feet, gray sandstone 24 feet, yields about 7 gallons a minute with small drawdown.
218	Hadley		Hillside	1,120	96			Gravel	Glacial drift	96		do.	Well does not reach bedrock.
219	2 miles south of Sheakleyville	C. C. Brush	Valley flat	1,100	93	4¼	85	do.	do.	93		do.	Sand and gravel 45 feet, blue clay 40 feet, gravel 8 feet.
220	Sheakleyville	John Graham	Valley	1,280	51	4¼		Sandstone	Upper part of Pottsville	26	18±	do.	Till and gravel 26 feet, sandstone 25 feet.
221	do.	Guy Kelsh	do.	1,280	50	4¼		do.	do.		20+	do.	Sandstone 50 feet.
222	do.	Herb Davis	do.	1,280	56	4¼		do.	do.	27	25	do.	Till 18 feet, sand 8 feet, gravel 1 foot, gray sandstone 29 feet.
223	Sheakleyville	W. C. Thompson	do.	1,300	50	4¼		do.	do.	26	20		Till 26 feet, gray sandstone 24 feet.
224	1 mile east of Sheakleyville	Andrew Smetanka	do.	1,200	73	4¼		do.	Middle of Pottsville	47	22	do.	Till, sand, and gravel 47 feet, gray sandstone 26 feet.
225	1 mile north of Sheakleyville	C. D. Limber	Hillside	1,300	50	4¼		do.	Upper part of Pottsville	29	20±	do.	Till 29 feet, sandstone 21 feet.
226	2⅔ miles northeast of Sheakleyville	John Dilley	do.	1,320	48	4¼		do.	do.	29	20±	do.	Till and gravel 29 feet, sandstone 19 feet.

227	New Vernon	A. J. Galager	do.	1,260	56	4¼	-------	do.	Lower part of Pottsville	24	24	do.	Till 24 feet, thin-bedded sandstone 56 feet. See analysis.
228	Stoneboro	Gus Doyle	Hilltop	1,420	90	4¼	-------	do.	Upper part of Pottsville	66	23	do.	Sand and gravel 66 feet, gray sandstone 24 feet.
229	do.	Clark Bros.	Hillside	1,320	61	5⅝	-------	do.	do.	33	25	do.	Till and gravel 33 feet, gray sandstone 28 feet.
230	do. [b]	Camp-meeting grounds	----------	---------	54	-----	15	do.	----------	15	------	do.	Till 15 feet, sandstone 39 feet.
231	do.	----------	Flat	1,180	53	-----	------	Gravel	Glacial drift	53	------	do.	Well does not reach bedrock.
232	4½ miles southeast of Henderson [b]	United Natural Gas Co.	----------	1,480	-------	-----	375	Sandstone	----------	-----	------	none	Gas well; water in sandstone between 375 and 420 feet.
233	2½ miles west of Millbrook	John Patterson	Slope	1,340	343	-----	-------	do.	Pocono	-----	40+	D.	Water reported to be highly mineralized and to have a slight odor of H_2S.
234	1 mile southwest of Millbrook	Jim Carroll	Valley flat	1,300	-------	5⅝	300±	do.	Upper part of Pocono	-----	Flows	none	Old oil well about 1,000 feet deep; water from about 300 feet flows about 100 gallons a minute and has a static head of more than 10 feet above ground level. See analysis.
235	2 miles south of Millbrook	----------	Valley	1,260	101	-----	-------	do.	Pottsville	-----	do.	D.	Water level about 4 feet above ground level.
236	2 miles north of Grove City	Matt Bowie	Slope	1,320	406	-----	-------	do.	Pocono group	-----	66	do.	Bedrock encountered at 28 feet.
237	do.	----------	do.	1,300	60	-----	-------	do.	Upper part of Pottsville	40±	25±	do.	Glacial drift 40 feet, sandstone 20 feet.
238	½ mile west of Grove City	----------	Flat	1,260	85	-----	-------	Gravel	Glacial drift	85	------	do.	Well does not reach bedrock.
239	Grove City	Cooper-Bessemer Co., well	do.	1,260	310	8	235	Sandstone	Upper part of Pocono	120	56	Ind.	Drawdown of 23 feet pumping 750 gallons a minute; this well is 10 feet from well 242 and 1,000 feet from wells 240 and 241. See analysis and log.
240	do.	Cooper-Bessemer Co., well 5	do.	1,260	293	8	-------	do.	do.	-----	40±	do.	Pumps 500 gallons a minute. See remarks under well 239.
241	do.	Cooper-Bessemer Co., well 4	do.	1,260	299	6	-------	do.	do.	-----	40±	do.	Pumps 400 gallons a minute. Spaced 10 feet from well 240. See analysis, and remarks under well 239.
242	do.	Cooper-Bessemer Co., well 3	do.	1,260	291	4	-------	do.	do.	-----	40±	do	Pumps 175 gallons a minute. See remarks under well 239.
243	do.	Grove City Borough	do.	1,260	350±	12	300±	do.	do.	-----	36±	P S	Drawdown about 6 feet pumping about 600 gallons a minute; has tested about 800 gallons a minute, though present pumping rate is 400 gallons a minute. See analysis.

Drilled wells in Mercer County (Continued)

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[d]	Remarks
244	Grove City	Grove City Borough	Flat	1,260	350±	12	300±	Sandstone	Upper part of Pocono		36±	PS	Drawdown and yield similar to well 243.
245	2 miles southeast of Grove City	do.	do.	1,260	78		76	Limestone	Vanport	76	10	D.	Sand 76 feet, limestone 2 feet.
246	3 miles southwest of Grove City		Valley	1,240	80			Gravel	Glacial drift	80		do.	Well does not reach bedrock.
247	do.		Hilltop	1,260	85			do.	do.	85		do.	do.
248	½ mile northeast of Leesburg	F. L. Offut	Valley	1,200	23		20	Sandstone	Pottsville	20	3	do.	Till 20 feet, sandstone 3 feet.
249	1 mile south of Leesburg		Hilltop	1,380	160			Gravel	Glacial drift	160		do.	Well does not reach bedrock.
250	1½ mile southwest of Mercer	Vest Turner	Hillside	1,180	37	4¼		do.	do.	37	16±	do.	Dark-brown sand and gravel 37 feet. See analysis.
251	1 mile northeast of Mercer		Valley	1,120	53			do.	do.	53		do.	Well does not reach bedrock.
252	do.		do.	1,100	145	5⅝		do.	do.	145			Entire depth in "quicksand"; abandoned because of small yield.
253	1 mile north of Mercer	C. Palmer	Hillside	1,260	62	4¼		Sandstone	Upper part of Pottsville	25	25	D.	Clay and sand 25 feet, sandstone 37 feet.
254	2½ miles northwest of Mercer	Will Crawford	Upland flat	1,320	200—	4¼		do.	Upper part of Pocono		40±	do.	Bedrock encountered at 15 feet.
255	2½ miles north of Mercer	O. Kelso	Hillside	1,260	70	4¼			Lower part of Pottsville formation	35	28	do.	Till 35 feet, sandstone 35 feet.
256	do.	L. Eckley	do.	1,200	70	4¼		do.	do.	18	25±	do.	Till 18 feet, sandstone 52 feet.

257	3 miles north of Mercer	J. M. McCulla	Valley flat	1,140	60	4½	-------	Shale	Upper part of Pocono	50	20±	do.	Gravel and sand 50 feet, "slate" 10 feet.
258	4 miles north of Mercer	Mrs. Shannon	do.	1,140	60	4¼	-------	do.	do.	25	23	do	Till and gravel 25 feet, shale 5 feet, "slate" 30 feet.
259	6 miles east of Sharon	Willlam Currie	Slope	1,190	68	-----	-------	Sandstone (?)	Upper part of Pottsville	-----	-----	do.	
260	1½ miles northeast of Sharon [b]	Old Sharon furnace	----------	----------	-------	-----	-------	----------	----------	-----	-----	none	Old oil well; fresh water in gravel at 46 feet, in shale at 175 feet, and in shale at 280 feet. [c]
261	Sharon [b] -------	Buhl Hospital	Hilltop	---------	345	6	-------	Sandstone	Pocono (?)	81	------	D.	
262	do. [b]	J. C. Hoffman	Hillside	---------	270	-----	220±	do.	do.	-----	------	do.	Water also encountered at 70 feet in sandstone.
263	do. [b]	Sharon Steel Hoop Co.	Valley flat	---------	165±	-----	-------	do.	do.	100	------	Ind.	Sand and gravel 100 feet, sandstone 65 feet.
264	Farrell [b] -------	Pulic Cash Market	Hillside	---------	85	-----	-------	do.	----------	-----	------	D.	Sandstone 85 feet.
265	West Middlesex	West Middlesex Borough	Valley flat	820	316	8	208	do.	Lower part of Pocono (?) -------	208	34±	P.S.	Bedrock encountered at 205 feet; another similar well in use; water level has been lowered about 20 feet in 7 years; drawdown about 15 feet pumping 187 gallons a minute for 5 hours. See analysis.
266	1 mile southeast of West Middlesex	Gulf Refining Co.	do.	820	307	-----	229(?)	do.	do.	229	60	Ind.	See log. Pumps about 12 gallons a minute. See analysis.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] Pennsylvania Second Geol. Survey, Rept. I³, p. 419, 1880.
[d] D=Domestic; Ind=Industrial; PS=Public Supply.

VENANGO COUNTY

GENERAL FEATURES

Venango County lies about in the center of the area described in this report. It has an area of 661 square miles. The population in 1930 was 63,226. Two of the twenty largest cities in northwestern Pennsylvania are in Venango County—Oil City and Franklin, with populations of 22,075 and 10,254, respectively. In 1930 there were 103 manufacturing establishments in the county.

Venango County is drained by Allegheny River and its tributaries, chief of which are French, Oil, Sugar, Sandy, and East Sandy creeks. Some of the streams in the northwestern part of the county flow on thick glacial valley filling, but most of the streams of the county flow in bedrock valleys. The region is one of rather rugged topography, with only small flat areas along the valleys and on the uplands. The steepest slopes occur along Allegheny River, where the valley walls in places rise more than 500 feet in a distance of less than a quarter of a mile. Numerous hills along the eastern county line are more than 1,700 feet above sea level, but along the western boundary most of the highest hills are only about 1,500 feet above sea level. The highest point in the county lies about 4 miles southeast of Pleasantville, near the Forest County line, and is 1,725 feet above sea level. The lowest point is less than 860 feet above sea level, in the Allegheny Valley in the southeast corner of the county. The greatest relief in the county is therefore about 965 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

Only about half of Venango County was covered by the Illinoian ice, the Illinoian glacial boundary extending from the northeast corner of the county to the southwest corner. The Wisconsin ice sheet covered only a small area in the western part of the county. The two glacial boundaries are shown on plate 4. The Allegheny Valley is the only valley south of the Illinoian glacial boundary that contains any appreciable amount of glacial outwash, and even here the thickness and areal extent of the deposit is not great. The valleys of French and Sugar creeks contain considerable glacial outwash, but its areal extent and thickness are by no means as great as in the counties to the north and northwest. The glacial outwash is typical in character consisting of irregular stratified layers and lenses of clay, "quicksand," sand, and gravel.

The sand and gravel of the glacial outwash will generally yield good to excellent supplies of water to drilled wells that are finished with screens and properly developed. The water is likely to be somewhat hard.

ROCK FORMATIONS

The rocks exposed in Venango County extend from about 100 feet above the Vanport limestone member of the Allegheny formation down to and including a part of the Pocono group. Over almost all the county the Pottsville formation constitutes the surface rocks. However, all the major streams have cut through the Pottsville and exposed the underlying Pocono. In the southern part of the county the Allegheny formation caps the higher hills.

The detailed geology of Venango County is but little known except for the deeper rocks, which have been penetrated by a great number of oil and gas wells.[8] Only small areas of the Allegheny formation occur in the southern part of the county, and in these areas the formation in a general way is probably similar to the Allegheny formation of the region to the southeast. Because of its small areal extent the Allegheny formation is of little value as a source of water. The Pottsville formation in Venango County consists of more or less massive sandstone with intervening shale members and in a rough way is similar to the Pottsville of the area to the east and west. The Homewood and Connoquenessing sandstones are recognized, and at the base of the Pottsville a sandstone that may represent the Olean conglomerate is also present. The sandstones of the Pottsville formation, where massive, generally yield moderate to good supplies of water that may be somewhat high in iron. The Pocono group exposed along most of the larger valleys is probably similar to the Pocono described in the section on Crawford County. The sandstones of the Pocono generally yield good to excellent supplies of water (see analysis 406) although in places where the sandstone is thin-bedded only small supplies are obtained. The water is generally of good quality but may be high in iron.

As in the adjoining areas, the beds in Venango County lie nearly horizontal, though minor irregularities in dip occur in places.

GENERAL GROUND-WATER CONDITIONS

Venango County is well supplied with ground water. In most of the county the surface rocks belong to the Pottsville formation, which in many places is rather sandy and moderately permeable, and shallow wells therefore usually yield ample water for domestic needs as well as for smaller industrial and municipal supplies. Most of the wells are drilled, though some dug wells are still in use, but because they are not reliable in the dry seasons they are gradually being replaced by deeper drilled wells. Because of the hilly character of the county and the occurrence along these hillsides of permeable sandstones, small springs are numerous and supply the domestic needs in many regions. As in other parts of northwestern Pennsylvania, many wells yield water high in iron, and the problem of obtaining a supply of ground water low in iron is in many areas a difficult one to solve. The sand and gravel of the glacial drift and the sandstones of the Pottsville formation and the Pocono group are the chief water bearers in the county. As shown on plate 4 the glacial outwash is restricted to the major valleys, and it is therefore only in these places that the outwash is a large producer of ground water. The Homewood and Connoquenessing sandstone members of the Pottsville formation and the sandstones of the Pocono group are fairly persistent as massive sandstones throughout the county, and therefore they can usually be relied upon to yield small to moderate supplies of ground water. In places, however, all these sandstones become so shaly that they yield very little water to wells drilled into them.

Although the structure of the rocks in Venango County is relatively simple, it is of such a character that in a number of places

[8] For a description of these wells see Carll, J. F., Pennsylvania Second Geol. Survey Rept. I², 1877, and I³, 1880.

water under artesian pressure is encountered. Commonly this pressure is not sufficient to cause the water to flow at the surface, though in some places flowing wells have been obtained. Wells 397, 402, 403, and 404 all encountered water that was under artesian pressure. Because the dip of the rocks is slight and also because the structure has not been mapped in detail, it is not possible to predict where flowing wells may be obtained in future drilling, although some wells of this kind will undoubtedly be drilled.

In the region around Franklin one driller reports that only small quantities of water are encountered in sandstones of the Pottsville formation and that in most wells ending in the sandstone of the Pocono group somewhat salty water is usually obtained. In the vicinity of Clintonville it is reported that most of the wells in use are dug wells 15 to 25 feet deep and that the water below that depth is usually hard and high in iron. The water level in this region is reported to stand 5 to 6 feet below the surface in most wells. About 1 mile below the junction of French Creek and the Allegheny River a spring issues from the east wall of the valley through joints in a sandstone that is probably in the upper part of the Pocono group. In 1925 the spring was reported to flow about 8 gallons a minute, but in 1928 the flow measured about 5 gallons a minute. The water is bottled and sold by the Big Rock Water Co.

QUALITY OF WATER

Analyses of waters from Venango County are tabulated on earlier pages. As in other parts of the area covered by this report, much of the ground water in Venango County is high in iron. The sandstones of both the Pottsville formation and the Pocono group are reported to yield waters that contain moderate to large quantities of iron. The waters from the glacial outwash along the major valleys do not in general contain excessive amounts of iron, and this deposit is therefore a much more desirable source of supply than the bedrock formations. In some places the Pocono group is reported to yield salty water and considerable quantities of hydrogen sulphide gas. Deep drilling is not advisable because of the likelihood of encountering salt water, although in some localities wells 500 feet deep are reported to yield fresh water.

PUBLIC SUPPLIES

With the exception of Emlenton all the towns in Venango County that have public supplies rely wholly or in part on ground water as a source. Oil City derives all of its supply from wells, and Franklin derives about half of its supply from wells. Several boroughs depend upon springs for their municipal supplies. The glacial gravel and the sandstones of the Pottsville formation and the Pocono group are the main sources for domestic supplies and for most of the municipalities. Both Oil City and Franklin are not any too abundantly supplied with ground water at the present time, and as future needs increase additional water supplies will have to be obtained. To some extent these increased needs can probably be met by putting down additional wells. Oil City could undoubtedly increase the amount of water at present pumped from its wells by eliminating the siphon that connects the wells with the booster pump. In this way larger quantities of water could be obtained by increasing the drawdown, which as shown by wells 405-411 is not large.

Public water supplies in Venango County

Town	Population, 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Emlenton	1,137	Emlenton Water Co.	Allegheny River			Gravity	220,000	144,000		Hypochlorite of lime, alum, sedimentation, filter
Franklin[a b]	10,254	Municipal	7 drilled wells, 1 dug well, French Creek	Glacial gravel and Burgoon sandstone	Suction	Gravity, direct	535,000	1,500,000	175+	Chlorine gas, alum, filter
Oil City[a]	22,075	do.	13 drilled wells, 2 dug wells	do.	Deep-well pumps, siphon	Gravity	4,980,000	3,000,000	110±	Chlorine gas
Pleasantville[a]	627	do.	6 drilled wells	Connoquenessing sandstone and Olean (?) rate conglome-	Deep-well pumps	Direct[c]	46,000	12,500+	75	None
Polk[d] Institution for Feeble Minded	---	State of Pennsylvania	5 springs, stream			Gravity	950,000	75,000	30	Chlorine gas, filter
Raymilton		W. D. Doyle	1 spring			do.	120			None
Reno		Venango Oil & Land Co.	5 springs			do.	171,000	8,400	85—	do.
Rouseville	1,059	Stone Hill Water Co.	2 springs, 2 drilled wells (Auxiliary)	Pocono group		do.	80,000	3,888		do.

[a] See analyses and record of wells.
[b] About 45 per cent of supply from wells.
[c] Excess to reservoir.
[d] Less than one-third of supply from springs.

Drilled wells in Venango County

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [m]	Remarks
387	Pleasantville	Pleasantville Borough	Upland flat	1,690	110	8		Sandstone	Connoquenessing			PS	Yields about 4 gallons a minute. See analysis. Drawdown in this well and well 388 is greater than in wells 389-392.
388	do.	do.	do.	1,690	110	8		do.	do.			do.	
389	do.	do.	do.	1,690	270	5⅝		do.	Olean (?) conglomerate member	20	90±	do.	Yields about 15 gallons a minute. See analysis.
390	do.	do.	do.	1,690	265	8		do.	do.			do.	
391	do.	do.	do.	1,690	275	8		do.	do.			do.	
392	do.	do.	do.	1,690	270±	8		do.	do.			do.	
393	do. [b]			1,683				do.	Connoquenessing(?)				Old oil well; water encountered at 140 feet in sandstone which was lost in dry crevice at 250 feet. [c]
394	Northeast part of Pleasantville [b]			1,583				do.	Olean (?) conglomerate member				Old oil well; water encountered at 162 feet in sandstone. [d]
395	3 miles southeast of Pleasantville [b]							Shale	Pocono (?)				Old oil well; water encountered at 40 feet in shale. [e]
396	do. [b]		Valley					Sandstone	Pocono				Old oil well; large quantity of water encountered at 170 feet in sandstone. [f]
397	4 miles southeast of Pleasantville [b]												Old oil well; water at 117 feet flowed about 1½ gallons a minute. [g]
398	4 miles southwest of Pleasantville [b]		Valley					Sandstone					Old oil well; large quantity of water encountered between 48 and 57 feet in sandstone. [h]
399	Cherry Run near Plumer [b]		do.					Shale					Old oil well; water encountered at 145 feet in shale. [l]
400	Rouseville	Stone Hill Water Co.	Hillside		250	6¼		Sandstone	Pocono			PS	This well together with well 401 pumps about 23 gallons a minute; water level is low in both wells.

401	do.	do.	do.	---	276	6¼	---	do.	do.	---	---	do.	---
402	3½ miles northwest of Rouseville	J. M. Huff	do.	1,480+	109	---	109	do.	Middle part of Pottsville	30	96±	D	Clay 30 feet, shale 30 feet, sandstone 49 feet; small quantity of water encountered at a depth of 30 feet; water at 109 feet reported to come from "erveiee."
403	1½ miles northwest of Oil City	O. L. Cook	Upland flat	1,540+	122	---	107	do.	Lower part of Pottsville (?)	11	48	do.	Clay 11 feet, hard sandstone 111 feet; water encountered at depths of 50, 87, 90, and 107 feet; small drawdown by bailing at 107 feet.
404	1 mile northwest of Oil City	Otto McFarland	Divide	1,520+	124	---	110±	do.	do.	18	104	do.	Clay 18 feet, sandstone 62 feet, limestone (?) 15 feet, sandstone 29 feet; well was dry at a depth of 105 feet; water rose about 5 feet when encountered.
405	2 miles southeast of Oil City	Oil City, wells 2—10	Valley	1,000	50	12	---	Gravel	Glacial drift	50	30±	PS	9 similar wells.
406	do.	Oil City, well 1	do.	1,006	63	12	---	Sandstone	Pocono	63	30	do.	Drawdown 6⅔ feet pumping 636 gallons a minute for 2 hours. See analysis.
407	do.	Oil City, well 17	do.	1,023	63	12	---	do.	do.	63	38	do.	Drawdown 2.9 feet pumping 557 gallons a minute for 2 hours.
408	do.	Oil City, well 18	do.	1,024	63	12	---	do.	do.	63	40	do.	Drawdown 4.8 feet pumping 303 gallons a minute for 2 hours.
409	do.	Oil City, well 19	do.	1,023	63	12	---	do.	do.	63	41	do.	Drawdown 4.7 feet by pumping 576 gallons a minute for 2 hours.
410	do.	Oil City, dug well 1	do.	1,010	43	---	---	Gravel	Glacial drift	43	---	do.	Dug well 12 feet in diameter, brick lined; tested about 2,000 gallons a minute. See analysis.
411	do.	Oil City, dug well 2	do.	1,014	38	---	---	do.	do.	38	---	do.	Dug well 20 feet in diameter; brick lined; tested 291 gallons a minute. See analysis.
412	Reno [b]	---	---	1,020±	---	---	---	Sandstone	---	---	---	---	Old oil well; large quantity of water encountered at 78 feet in sandstone. [j]
413	2 miles west of Seneca [b]	Diamond Bros.	---	---	275	5⅝	200	---	---	---	200	---	Water reported as "iron water." [k]
414	Southern part of Franklin	Venango Manufacturing Co.	Terrace	980	35	10	---	Gravel	Recent alluvium	35	25—28	Ind	Drawdown less than 4 feet pumping about 27 gallons a minute; well is pumped 24 hours a day during certain seasons. See analysis.
415	Franklin [b]	Franklin Valveless Engine Co.	do.	980	78	4¾	---	Shale	Pocono	41	48	do.	Pumped 2,100 gallons a day.
416	1½ miles west of Franklin	Franklin	Valley	1,000	38	---	---	Gravel	Glacial drift	38	20±	PS	Dug well 10 feet in diameter ending on rock into which are drilled 4 wells 6¼ inches in diameter. See analysis.

Drilled wells in Venango County (Continued)

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water	Remarks
417	1½ miles west of Franklin	Franklin	Valley	1,000	40	6¼		Sandstone	Pocono		20±	PS	4 similar wells drilled in the bottom of the dug well; water encountered 13 feet below top of rock; about 120 feet below top of rock highly mineralized water was encountered and had to be plugged off.
418	do.	do.	do.	1,000	40±	6¼		Gravel (?)	Glacial drift	40±	20±	do.	7 similar wells; these and well 416 yield about 600 gallons a minute. See analysis.
419	do.	Franklin Creek Refining Co.	Flood plain	990	55±	6¼		Gravel	Recent alluvium		20	Ind	About 5-foot drawdown by pumping about 75 gallons a minute. See analysis.
420	½ mile north of Sugar Creek	C. J. Weaver	do.	1,020+	43	5⅝		do.	Recent alluvium	40	10	D	Gravel 40 feet, "hard pan" 3 feet; small drawdown; water reported to be very hard.
421	1½ miles southwest of Franklin		Hillside	1,480+	60	5⅝		Sandstone	Lower part of Pottsville	20	40	do.	Clay 20 feet, sandstone 40 feet.
422	3½ miles southwest of Franklin	Guy Curtis	Flat	1,510+	105				do. (?)		25	do.	
423	Polk	John Bond	Flood plain	1,060+	75			Gravel and sand	Recent alluvium	30	20	do.	Gravel and sand 30 feet, shale 45 feet; small drawdown reported.
424	1½ miles west of Polk	J. Hovis	Hillside	1,440+	90+			Sandstone	Lower part of Pottsville (?)	8		do.	Sand and clay 8 feet, white sandstone 80+ feet.
425	1 mile northwest of Raymilton	Fay Lynn	Divide	1,460+	86	5⅝		do. (?)	do.	16	48	do.	Blue clay 19 feet, sandstone 32 feet, shale 35 feet; small drawdown.
426	1½ miles northwest of Wesley	Gilbert Wilele	Near hilltop	1,500+	105	5⅝		Gravel	Glacial drift	105	20	do.	Well does not reach bedrock.
427	Wesley		Gentle hillside	1,420	65	5⅝	40±	Sandstone	Homewood		40	do.	Clay 20 feet, shale 20 feet, white sandstone 25 feet; water reported to be "somewhat hard."

428	Nectarine	Surrena	Hillside	1,380	25			Sandstone (?)	Lower part of Allegheny	15	do.	Surface 15 feet, "slate" 10 feet.
429	½ mile northeast of Nickleville	Mars Co.	Valley	1,300						5	do.	Old oil or gas well; water encountered at 98 feet.

[a] Altitude taken from nearest 20-foot contour.
[b] Not located on map.
[c] Pennsylvania Second Geol. Survey Rep. I², p. 14, 1877.
[d] Idem, p. 12.
[e] Idem, p. 147.
[f] Idem, p. 150.
[g] Idem, p. 151.
[h] Idem, p. 161.
[i] Idem, p. 152.
[j] Idem, p. 208.
[k] U. S. Geol. Survey Bull. 298, p. 144 (no. 1401), 1906.
[m] D=Domestic; Ind=Industrial; PS=Public Supply.

WARREN COUNTY

GENERAL FEATURES

Warren County lies along the New York State line next to Erie and Crawford counties. The county is rectangular and has an area of 902 square miles, which makes it the second largest county in the area here described. In 1930 its population was 41,453. Warren, with 14,863 inhabitants, is the only borough in the county with a population of more than 2,000. In 1930 there were 132 manufacturing establishments in the county.

Warren County is mostly drained by Allegheny River and its tributaries. The southwestern part of the county is drained by Caldwell Creek, which joins Oil Creek near Titusville, in Crawford County. Tionesta Creek drains the southeastern part of the county and does not join Allegheny River until it reaches Tionesta, in Forest County. Most of the major streams flow in valleys deeply filled with glacial drift. Except between Warren and Irvine, however, the Allegheny River flows in a narrow V-shaped valley with steep rock walls. Swamps are numerous along some of the drift-filled valleys.

Warren County has a rather rugged surface, there being only small isolated areas of nearly flat land in the upland regions and long, narrow flats along some of the streams. Some of the steepest slopes occur along the Allegheny Valley in the eastern part of the county, where the valley walls rise more than 700 feet in less than half a mile. Near the northwest corner of Elk Township one hilltop is more than 2,220 feet above sea level. The altitude of the bottom of the Allegheny Valley where it crosses the southern county line is less than 1,080 feet. The maximum relief of the county is therefore more than 1,100 feet.

GEOLOGY AND GROUND WATER

SURFACE DEPOSITS

At least two separate ice sheets covered parts of Warren County during the glacial invasion from the north. These were the Wisconsin and Illinoian glaciers, and their greatest southward extension is shown on plate 4. Leverett[1] is of the opinion that the high-level glacial deposits in the vicinity of Clarendon are pre-Illinoian. They are, however, included within the Illinoian glacial boundary on plate 4. Along many of the valleys the glacial outwash forms terraces at different heights above the streams. (See pl. 9, A.)

In general both the Wisconsin and Illinoian tills are thin on the uplands, especially the Illinoian, for in places it is represented only by a few scattered pebbles, some of which are derived from igneous rocks. The distribution and thickness of glacial outwash is shown on plate 4. The well at Lottsville (well 339) shows one of the greatest thicknesses of glacial outwash in northwestern Pennsylvania.

The sand and gravel of the glacial outwash generally yield good to excellent supplies of water to drilled wells that are screened and properly developed. The water is generally of good quality.

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[1] Leverett, Frank, Nat. Research Council, Report of the Committee on Sedimentation, p. 46., 1927.

ROCK FORMATIONS[9]

The rocks that crop out in Warren County extend from about the top of the Pottsville formation down to and including about 200 feet of the Chemung formation. With the exception of a few outliers, the Pottsville formation is limited to the area southeast of the Allegheny River, where it caps the upland divides. The Chemung formation is exposed only along the valleys of the Allegheny River nearly to Kinzua, Conewango Creek almost to Warren, Kiantone Creek to a point about 1 mile northeast of Lauder, Stillwater Creek nearly to Sugar Grove, and Little Brokenstraw Creek almost to Lottsville. Over the remainder of the county the Poeono group (Cuyahoga and Berea formations) and the Knapp and Conewango formations are exposed. The following generalized section shows the roeks exposed in the Warren quadrangle:[10]

Generalized section of rocks exposed in Warren quadrangle

Formation	Thickness (feet)	Lithologic character
Pottsville formation	0–200	Coarse quartz sandstone and round quartz-pebble conglomerate, divided by dark shale containing limonite nodules and thin streaks of coal.
Unconformity.		
Cuyahoga formation	5–200	Green shale and thin fine-grained green sandstone and flat-pebble conglomerate.
Berea sandstone	2–5	Highly fossiliferous sandstone.
Knapp formation	80	Flat-pebble conglomerate, generally divided by a bed of shale. Lower conglomerate usually highly ferruginous. Fossiliferous throughout.
Conewango formation	510–560	Thin greenish shale and thin-bedded green and gray sandstone and conglomerate, with a few beds of red shale. Sparsely fossiliferous.
Chemung formation	200+	Purplish clay shale and thin purplish flaggy sandstone mixed with gray and greenish shale and sandstone. "Pink rock" of oil-well drillers.

Allegheny and Pottsville formations. Two small areas of the Allegheny formation are shown in plate 5 along the eastern line of Warren County. This appears to be an error, because no areas of the Allegheny formation are shown on the geologic map of Warren County in Report I[4] of the Pennsylvania Second Geological Survey. However, the geologic map of McKean County, to the east, in Report R of that Survey, shows two areas of the Lower Produetive Coal Measures along the Warren County line that would extend into Warren County. The McKean County map, however, does not use the term "Lower Produetive Coal Measures" in its usual sense, but includes in it the Mercer (Alton) coals and the Homewood (Johnson Run) sandstone member, both of whieh belong in the Pottsville formation. There appears, therefore, to be none of the Allegheny for-

[9] The descriptions given here are taken mainly from J. F. Carll, (Pennsylvania Second Geol. Survey Rept. I[4], 1883), and Charles Butts, (U. S. Geol. Survey Geol. Atlas, Warren folio (no. 172), 1910).

[10] Butts, Charles, op. cit., p. 3.

mation remaining in Warren County. The Homewood sandstone and Mercer shale members occupy such small areas in this county that little is known of them. The Connoquenessing (Kinzua Creek) sandstone member is a very coarse white quartz rock which in some localities contains a few small rounded pebbles. Just south of the Allegheny River near Big Bend it has a thickness of about 100 feet. Below the Connoquenessing occurs the Sharon shale member, which is 40 feet thick in places. It consists of soft dark shale, somewhat sandy in places, and contains thin coals and iron nodules. In the eastern part of the county its thickness is probably not over 30 feet. The Olean conglomerate is the basal member of the Pottsville formation in Warren County. It is believed to correspond to the Sharon conglomerate member to the west and southwest. The uneven surface on which it was deposited is described on page 36, and because of this irregular surface the member has a wide range in thickness. In the Warren quadrangle its greatest thickness is 50 feet. The rock is coarse and generally composed of rounded white quartz pebbles, the largest of which are about 2½ inches in diameter. These pebbles are embedded in a matrix of fine quartz grains. The whole mass is in many places prominently cross-bedded. The Olean appears to become thinner to the south, for it is only 2 to 6 feet thick between Sheffield and Tidioute. The "Rock Cities" southwest of Scandia on the road to Warren, Pikes Rocks (see pl. 9B), and other well-known features in the county are composed of the Olean conglomerate.

The Pottsville formation is not a noteworthy source of water because of its small areal extent. However, where it is thickest moderate supplies may be obtained from the massive sandstone members.

Pocono group.—The unconformity between the rocks described above and the Mississippian series is discussed on page 36. Great thicknesses of sediments which had been deposited in this region were removed by erosion before the Pennsylvanian series was laid down. Carll[11] described what he called the "sub-Olean conglomerate" and thought it to be the equivalent of the Shenango sandstone of I. C. White in Mercer and Crawford counties. Butts,[12] however, has shown that the true position of the Shenango of White (Burgoon sandstone) in Warren and McKean counties lies 300 feet or more above the sub-Olean and that it has been completely removed by erosion in that area. The Cuyahoga is therefore the highest formation of the Mississippian series present in Warren County. It is made up mostly of dark sandy shale with thin sandstone or conglomerate beds as much as 10 feet thick. The pebbles in the conglomerate are flattish, a feature that is characteristic of all the pebbly rocks below the Pennsylvanian series and in contrast to the rounded pebbles of the conglomeratic rocks of Pennsylvanian age. The Berea sandstone appears to thin noticeably eastward into Warren County and probably wedges out completely in this area.

Knapp and Conewango formations.—In Warren County the Knapp and Conewango formations underlie the Berea sandstone and overlie

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[11] Carll, J. F., op. cit., pp. 189-195.

[12] Butts, Charles, Pre-Pennsylvanian stratigraphy: Pennsylvania Top. and Geol. Survey Comm. Rept. for 1906-8, p. 193, 1908.

PLATE 9.



A. Exposure of terrace along Little Brokenstraw Creek about 2½ miles south of Wrightsville, Warren County.



B. Pikes Rocks, 2 miles northeast of Wrightsville, Warren County.

the Chemung formation. They are of Upper Devonian or Mississippian age. The Knapp formation, the younger, is divided into three members, which are, from top to bottom, conglomerate 20 to 60 feet thick, shale and fine-grained sandstone 10 to 40 feet thick, and conglomerate 20 to 30 feet thick. In the Warren quadrangle the greatest thickness of the Knapp is about 120 feet. The upper conglomerate ranges from a thin-bedded sandstone to a dense conglomerate made up of flat quartz pebbles half an inch or less in diameter. This member is about 100 feet thick 5 miles south of Scandia, but it appears to thin toward the southwest, for a few miles southwest of Warren it is only about 20 feet thick and has lost its conglomeratic character. The village of Scandia is built on a flat formed by this member. The shale member in the middle of the formation is not everywhere present but in general is thickest in the southwestern part of the Warren quadrangle. Although the lower conglomerate member is coarse and resistant in some localities, it is generally made up of small iron-stained quartz pebbles with much iron oxide in the matrix.

The Conewango formation has a thickness of about 550 feet and is divided about in half by the Salamanca conglomerate. The rocks above the Salamanca are mainly greenish sandy shale with thin fine-grained greenish sandstone. The Salamanca conglomerate is persistent throughout Warren County and ranges in thickness from about 10 to 20 feet. The rock may be coarse and conglomeratic, composed of flat white quartz pebbles as much as an inch in diameter, or it may be medium-grained, medium-bedded, and rather friable. The rock is usually white but may be somewhat mottled with iron stains. The part of the Conewango formation below the Salamanca conglomerate is similar to the upper part of the formation, except that beds of gray sandstone and conglomerate a few feet thick occur. They are probably lenticular, however, and not of widespread occurrence. About 100 feet above the base of the Conewango formation red shales as much as 20 feet thick are present in some localities. In places red shales are also associated with the Salamanca conglomerate. Butts,[13] on fossil evidence and because of the relations of red shales to the Salamanca conglomerate, in the Warren and adjoining regions, considers the Conewango formation to be contemporaneous with some part of the Catskill formation of the area to the east.

Chemung formation.—Although the Chemung formation in Warren County is more than 1,000 feet thick, only about 200 feet is exposed. About the upper 450 feet of the Chemung is made up of purplish or chocolate-colored shale or fine-grained sandstone interbedded with gray and greenish shale and sandstone. These rocks are known as the "pink rock" among the well drillers of the area. The top of the "pink rock" marks the top of the Chemung formation. Essentially all of the oil produced in the county comes from the lower part of the Chemung formation.

The rocks of Warren County have a general dip to the south or a little west of south at the rate of about 15 to 20 feet to the mile. In places there are minor reversals of dip that give rise to dome-like structure, but with two exceptions these features have not been worked

[13] Butts, Charles, U. S. Geol. Survey Geol. Atlas, Warren folio (no. 172), p. 4, 1910.

out in detail. The axis of the Kinzua-Emporium cross anticline trends about northwest and dies out near the Allegheny River 3 miles west of Big Bend. The Morrison Run anticline occurs in the region about the headwaters of Morrison Run, and the axis is approximately parallel to the valley. The structure is in reality a dome rather than an anticline.

The massive sandstones of the Pocono group and of the Knapp, Conewango, and Chemung formations generally yield moderate supplies of water to drilled wells. Where the rocks are shaly only small quantities are obtained. The water is generally of good quality but may be somewhat salty if encountered at considerable depths.

GENERAL GROUND-WATER CONDITIONS

Warren County is moderately well supplied with ground water. Small springs are numerous and are utilized in many parts of the area. Dug wells are in use in places, but they are gradually being abandoned because of the likelihood of contamination and because they may go dry in the dry season. Driven wells are used in some localities along the major streams. Drilled wells are the most common type of well in the county. Many of the wells that furnish domestic supplies are 4 inches in diameter, but the industrial and municipal supplies are derived from larger wells. From the data tabulated in the table of drilled wells it appears that moderate supplies can be obtained over much of the county from wells less than 100 feet deep. This seems to be true irrespective of the type of rock yielding the water. However, there are undoubtedly places in the county where it is difficult to obtain moderate quantities of water in the first 100 feet, and in such places deeper drilling is necessary.

Along the major valleys that contain deposits of glacial outwash abundant supplies are usually available. As in other parts of northwestern Pennsylvania, this is the most promising source for large quantities of ground water. On the uplands above these valleys water in moderate quantities can generally be obtained from the Chemung or the Conewango formation, but the quantities will usually not be large.

Flowing wells are common in parts of the area where the structure of the rocks is such that artesian conditions exist. (See wells 366 and 376.) Many of the wells listed in the table encountered artesian water, and in a number of them the artesian pressure was great enough to produce flowing wells. In the Conewango Valley in the vicinity of Russell and Ackley flowing wells are obtained in the glacial outwash. (See wells 356, 357, and 360.) According to the report of one driller, all the wells along this valley are flowing wells.

QUALITY OF WATER

Analyses of six waters from Warren County are tabulated on an earlier page. They are all of similar quality, but generalizations for the county as a whole cannot be made on so few analyses.

In many parts of the county salt water is encountered relatively near the surface. The following table lists a number of oil and gas wells that were drilled about 1900 in the vicinity of Grand Valley.

Depths at which salt and fresh water were encountered in wells drilled for oil and gas in vicinity of Grand Valley in southwest part of Warren County

Depth at which salt water was encountered (feet)	Depth at which fresh water was encountered (feet)	Depth at which salt water was encountered (feet)	Depth at which fresh water was encountered (feet)
150–200; 334–355	100–135	411–459	
150–170			
170		416–420; 420–443 (rose to 200 feet below surface)	200–240 (flows 2 gallons a minute ?)
187–213	50–187		
205–245 (rose to 100 feet below surface)			
210–250	50–100	418–448	
224–244	198–210 (flow 10 gallons a minute)	425–455	100–141 (flows 2½ gallons a minute) (?)
226–263 (rose to 106 feet below surface); 460–478 (rose to 200 feet below surface)		433–447 (large quantity)	404–430 (rose to about 100 feet below surface)
230–242		442 (rose to about 300 feet below surface)	
250–280; 290–292	50–200	**443–473; 696–712** (rose 50 feet)	
240	60–116 (flow 5 gallons a minute ?)		80–219
257–300		465–478	435–461 (tested 500 barrels in 24 hours with small drawdown)
269	50–180		
280–290; 745	50–200		
	295–296		80–250
	300–317 (large quantity)	475–501	
305; 560	100	492	
305–325; 560–570; 785–807		507 (large quantity)	
310–332 (small quantity)	50 (large quantity)	537–587	
	20–184 (rose nearly to surface)	565; 775	
313		565–585; 825–831 (rose to about 600 feet below surface)	
315–345; 576–588 (rose to about 380 feet below surface)		638–642	50–200
	50–150	661–674 (rose 60 feet)	50–180
333–550; 767–797	275–305	702–718	
335		706–715	
348–357; 360–379		706–715	
358		712–742	
383–393	152–182	750	
384–402		776–789	
		815–820	

The above table shows that salt water may be encountered as near as 150 feet below the surface. In a number of these wells both the salt and the fresh water were under artesian pressure. In those wells in which beds carrying salt water are listed at greater depths, it should not be assumed that the rocks were saturated with fresh water down to those depths. It seems more probable that in many wells the given depth merely means the depth at which moderate or large quantities of salt water were encountered. Several other wells in Grand Valley obtained fresh water at less than 300. Two of them flow 3½ and 5 gallons a minute. One well in glacial drift was water-bearing throughout a depth of 284 feet.

PUBLIC SUPPLIES

The public water supplies of Warren County are listed in the next table. Tidioute is the only borough in the county that is entirely dependent upon surface water for its municipal supply. Warren derives about half of its yearly supply from three drilled wells. All the boroughs appear to have sufficient water to meet their present needs, and if future developments are carefully planned adequate ground-water supplies can be obtained for some time to come.

Public water supplies in Warren County

Town	Population, 1930	Owner	Source	Geologic source	Method of lift	Distribution	Storage (gallons)	Average daily consumption (gallons)	Pressure (pounds per square inch)	Treatment
Clarendon[a]	938	Clarendon Water Co.	drilled wells	Conewango formation			47,000			
Sheffield		Sheffield Water Co.	Springs, Deerlick Creek			Gravity	[b]		67+	None
Sheffield	[d]	Central Pennsylvania Lumber Co.	3 springs, 2 drilled wells			do.	25,000			
Tidioute	970	Tidioute Water Co.	Tidioute Creek				[b]	150,000	50	Hypochlorite of lime
Warren[e f]	14,863	Warren Water Co.	4 drilled wells, Morrison Run	Glacial gravel	Suction	Direct[g]	1,000,000	1,500,000	135—	Chlorine gas, lime, alum, sedimentation, filter
Youngsville[e f]	1,907	Municipal	7 drilled wells	Shale of upper part of Chemung formation	do.	do.	420,000		100—	None

[a] See record of wells in next table.
[b] Impounding reservoir.
[c] Almost 100 percent from springs.
[d] Serves 550.
[e] 50 per cent from wells.
[f] See analysis and record of wells.
[g] Excess to reservoir.

Drilled wells in Warren County

Map No.	Location	Owner	Topographic position	Altitude [a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water [p]	Remarks
339	½ mile northwest of Lottsville	----------	Valley flat ----	1,400	450	-----	-------	----------	Glacial drift ----	450	------	-----	Well does not reach hedrock[b]
340	2 miles east of Wrightsville	George Dunn ---	Upland flat ----	1,900	62	-----	-------	Sandstone	Upper part of Cuyahoga -----	-----	48	D.	10 feet to hedrock; small drawdown reported; water reported to be fairly hard.
341	Garland -------	Pennsylvania Railroad	Valley flat ----	1,300	86	-----	-------	Gravel	Glacial drift -----	86	12	do.	Till 28 feet, blue clay 28 feet, clay and gravel 20 feet. See analysis.
342	Pittsfield ------	do.	do.	1,240	78	-----	-------	do.	do.	78	12	do.	Till 25 feet, blue clay 35 feet, clay and gravel 18 feet.
343	Youngsville ---	Youngsville Borough	do.	1,200	70	5⅝	-------	Shale	Upper part of Chemung ----	70	16±	P S	7 similar wells spaced 40 feet apart; gravel 40 feet, shale 30 feet. See analysis.
344	do.	do.	do.	1,200	140	5⅝	-------	do.	do.	80	------	do.	Gravel 80 feet, shale 60 feet.
345	do.[c]	O. B. Houpin --	do.	1,200+	40	-----	-------	Gravel	Glacial drift -----	40	16	D.	Gravel 8 feet, "hardpan" 5 feet, gravel 27 feet.
346	1½ miles south of Irvine	J. M. Crull ----	do.	1,160	18	-----	-------	Sand and gravel	do.	-----	14	do.	Dug well about 5 feet in diameter.
347	Irvine ----------	----------	Terrace --	1,200	86	-----	-------	Sandstone (?)	Upper part of Chemung ----	42±	14	do.	Till 30 feet, blue clay 12 feet, "slate" 44 feet.
348	5 miles west of Warren	John Jaggie ----	Valley flat ---	1,160	23	¾	-------	Gravel	Recent alluvium	23	15	do.	Driven well; loam 8 feet, "hardpan" 18 inches, loose gravel 13 feet.
349	4 miles west of Warren	----------	Terrace --	1,200	65	4	-------	Sandstone (?)	Conewango	60	19	do.	Sand and gravel 55 feet, "slate" 10 feet.
350	do.	----------	do.	1,200	45	4	-------	Gravel	Glacial drift -----	45	20±	do.	Well does not reach bedrock.
351	do.	----------	do.	1,200	66	4	56	do.	do.	66	30	do.	Gravel, sand and clay 58 feet, "slate" 8 feet.
352	Lander ----------	Church ----------	Slope ---	1,570	86	-----	-------	Sandstone (?)	Conewango	33±	22	do.	Yellow clay 19 feet, blue clay 14 feet, "slate and shell" 53 feet.

353	2 miles northwest of Russell		Hilltop	1,810	84	4		do.	do.	28	14	do.	Yellow clay 24 feet, "slate" 60 feet.
354	2½ miles north of Russell		Valley flat	1,240									Oil well 1,200 feet deep; 216 feet to bedrock, yellow clay 16 feet, blue clay 200 feet.
355	2 miles north of Russell		do.	1,240			100						Oil well 1,300 feet deep, large supply of water encountered at 100 feet; also water in shale at 260 feet.
356	1½ miles north of Russell		do.	1,240	92	4	87	Gravel	Glacial drift	92	flows	D.	Blue clay 87 feet, gravel 5 feet.
357	½ mile north of Russell		do.	1,240	131	6	123	do.	do.	131	do.	do.	Yellow clay 18 feet, blue clay 105 feet, gravel 8 feet.
358	Russell	Fred Rickerson	do.	1,240	51	4		do.	do.	51	4	do.	"Quicksand" 30 feet, gravel and sand 21 feet. See analysis.
359	1 mile southwest of Russell		Hilltop	1,760				Shale			12		Oil well 1,776 feet deep; water in shale.
360	1 mile southeast of Russell		Valley flat	1,280	41	2		Gravel	Recent alluvium		flows	D.	Driven well; static level about 15 feet above ground level; flowed 8.1 gallons a minute on Aug. 9, 1928, and 7.5 gallons a minute on Sept. 26, 1928. See analysis.
361	2 miles southeast of Russell		do.	1,360	51			Sandstone (?)	Upper part of Chemung	34±	8	do.	Clay and gravel 34 feet, "slate" 17 feet.
362	3½ miles southeast of Russell		Valley	1,660			80		Conewango				Oil well 1,800 feet deep; water at 80 feet; 18 feet to bedrock.
363	3 miles south of Russell		Valley flat	1,240	54	4		Gravel	Glacial drift	54	28	D.	Well does not reach bedrock.
364	2 miles northwest of Warren		Valley	1,560	42	4		Sandstone (?)	Conewango	35	30	do.	Sand and gravel 32 feet, "slate" 10 feet; small drawdown reported.
365	do.		Slope	1,500	42	4		do.	do.	35	16	do.	Gravel and sand 32 feet, "slate" 10 feet.
366	do.		Hillside	1,500	36	4		do.	do.	28	flows	do.	Sand and gravel 24 feet, "slate" 12 feet.
367	½ mile northeast of Warren[c]						226						Old oil well 675 feet deep; fresh water at 226 feet; salt water at 370 feet.[d]
368	1 mile northeast of Warren[c]						205+	Sandstone					Old oil well 625 feet deep; water in sandstone from 205 to 223 feet.[e]
369	3 miles northeast of Warren[c]						232+	do.					Old oil well 1,400 feet deep; fresh water in sandstone from 232 to 290 feet.[f]

Drilled Wells in Warren County (Continued)

Map No.	Location	Owner	Topographic position	Altitude[a] (feet)	Depth (feet)	Diameter (inches)	Depth to principal water-bearing bed (feet)	Character of water-bearing material	Geologic horizon	Length of casing (feet)	Depth to water level (feet)	Use of water[b]	Remarks
370	Warren[c]						145						Old oil well 630 feet deep; water at 145 feet.[g]
371	1 mile south of Warren		Hillside	1,280	89	4		Shale	Conewango	75	49	D.	"Iron water" reported at contact of gravel and shale at 71 feet.
372	1½ miles southeast of Warren		Slope	1,240			140						Old oil well 780 feet deep; fresh water at 140 feet; salt water at 512 feet.[h]
373	do.		do.	1,240			200						Old oil well 1,000 feet deep; fresh water at 200 feet; salt water at 475 feet.[i]
374	2 miles southeast of Warren	Warren Water Co.	Valley flat	1,190	70±	8		Gravel	Recent alluvium	70±		P S	4 similar wells 150 to 300 feet apart; in dry season 4 wells together yield 1,220 gallons a minute with 11-foot drawdown pumping 24 hours a day. See analysis.
375	do.		River island	1,180			6	do.	do.			none	Oil well 750 feet deep; 62 feet to bedrock; "pink" rock encountered at 120 feet.
376	3½ miles southeast of Warren	O. D. Ruhlman	Flat	1,260		10	68±	Sandstone	Lower part of Conewango		flows	D.	Old oil well about 900 feet deep, which is plugged at 78 feet; flows about 25 gallons a minute; static water level is about 12 feet above ground. See analysis.
377	Clarendon		Valley flat	1,420									Oil well 1,000 feet deep; blue clay, gravel, and "quicksand", top 300 feet.
378	do.[c]	Clarendon Water Co.	do.		150		125	Sandstone (?)	Conewango	125±	50	P S	"Quicksand" blue clay, and gravel 125 feet, "slate" 25 feet.
379	2½ miles northeast of Clarendon		Hilltop	1,940			120	Shale	Knapp		100		Oil well 1,400 feet deep; water at 120 feet in shale; 20 feet to bedrock.
380	2½ miles east of Sheffield[c]						70						Old oil well 1,645 feet deep; water at 70 feet; salt water at 418 feet.[c j]
381	Sheffield[c]	Pennsylvania Lumber Co.			150			Sandstone (?)	Chemung	70±	40±	D.	Gravel 70 feet, "slate" 80 feet.

382	1½ miles southeast of Tidioute bridge[c]						71	Sandstone					Old oil well 562 feet deep; water in sandstone at 71 feet.[k]
383	1 mile southeast of Grand Valley[c]						110±				90		Old oil well 580 feet deep; fresh water between 100 and 120 feet; salt water between 528 and 536 feet.[l]
384	do.[c]						80	Sandstone			160		Old oil well 610 feet deep; fresh water which falls to 160 feet at 80 feet in sandstone; salt water at 557 feet.[m]
385	do.[c]												Old oil well 529 feet deep; fresh water at 25 to 100 feet; salt water at 480 to 491 feet.[n]
386	1 mile east of Grand Valley[c]												Old oil well 659 feet deep; about 2½ gallons a minute of fresh water at 106 to 170 feet.[o]

[a] Altitude taken from nearest 20-foot contour.
[b] Pennsylvania Second Geol. Survey, Report I⁴, pp. 233–236, 1883.
[c] Not located on map.
[d] Pennsylvania Second Geol. Survey Report I⁴, p. 4, 1883.
[e] Idem, p. 6.
[f] Idem, p. 15.
[g] Idem, p. 2.
[h] Idem, p. 7.
[k] Pennsylvania Geol. Survey Rept. I², p. 179, 1877.
[l] Idem, p. 8.
[k] Pennsylvania Second Geol. Survey Rept. I², p. 179, 1877.
[j] Idem, p. 379.
[l] U. S. Geol. Survey, Bull. 298, p. 140 (no. 1370), 1906.
[m] Idem, p. 140 (no. 1371).
[n] Idem, p. 140 (no. 1372).
[o] Idem, p. 142 (no. 1389).
[p] D=Domestic; Ind=Industrial; PS=Public Supply.

INDEX

A

Ackley, flowing well at, 205
Adrian, 162, 163
Aeration, 52
Aftonian interglacial stage, 27
Albion, 57, 62, 133-135
Aliquippa, 61, 91, 94
Allegheny formation, 32, 67, 80, 96, 148, 158, 168, 179, 193, 202
  water in, 172
Allegheny River, 23, 25
  analysis, 59, 63
  terrace deposits, 29, 141
Alluvium, recent, 26
Althorn, 25
Ambridge, 91, 94
Ames limestone, 79
Analyses, 54-63, 87, 88
Apollo, 72
Appalachian Plateau Province, 12
Applewold, well at, 54, 72, 75
Armstrong County, analyses of waters, 54, 61
  ground water in, 65-75
Artesian conditions, 45, 70, 84, 102, 116, 152, 162, 172, 183, 194, 205
Avonmore, 75

B

Baden, 55, 91, 94
Barr, 154
Beaver, 54, 61, 86, 88, 91-93
Beaver Center, 121
Beaver County, analyses of waters, 54, 61
  ground water in, 76-94
Beaver Dam, 139
Beaver Falls, 77, 91, 92
Beaver River, 29
Bellowsville, 93
Berea sandstone, 39, 114
Bessemer, 176
Bigliography, 3-5
Big Brokenstraw valley, 25
Big Injun sand, 39, 69, 100
Big Run, 163, 165
Big Run Valley, 17
Black Ash, 124
Blairsville, 154
Blooming Valley, 125
Bluff sand, 34, 102
Boles Run, 110
Bredlinger, 154
Bridgewater, 91
Brockway, 163
Brookville, 163
  coal, 33, 98
Burgoon sandstone, 33, 38, 39, 69, 100, 102, 103, 114, 150, 182
Buried valleys, 16, 110
Butler sandstone, 67, 81

C

Cadogan, 72
Cambridge Springs, 56, 111, 120, 123
Carboniferous system, 31
Carmichaels formation, 29, 66, 77
Casing, 47
Catfish, 104
Catskill formation, 150
Chambersville, 154
Chemical composition, ground water, 49-63, 71, 86-88, 102, 116, 132, 152, 162
Chemung flags, 131
Chemung formation, 13, 130, 132, 202, 204
Cherry Run, 196
Cherrytree, 154
Chestnut Ridge, 12
Chewton, 58, 177
Chickasaw, 72
Clarendon, 28, 207, 210
Clarion, 55, 61, 62, 100, 102-104, 106
  coal, 97, 98
  county, analyses of waters, 55, 61
  ground water in, 95-108
  river, 15, 95
    analysis of water, 56, 62
    gravels, 30
  sandstone, 149
Clarksburg, 148
Clarks Mills, 187, 188
Clarksville, 187
Climate, 6
Climatologic stations, 7
Clintonville, 194
Clymer, 57, 63, 150, 152-154, 156
Coal, ground water in, 46, 152, 153
Coal mine water, 103, 153
Coaltown, 176
Cochranton, 56, 113, 120
College Hill, 91, 113
Colona, 91, 93
Commodore, 154
Concord, 139
Cone of depression, 48
Conemaugh formation, 32, 67, 79, 96, 146, 158, 168
Conemaugh River, 15, 30
Conewango Creek, 25
Conewango formation, 39, 43, 115, 202, 204
Conewango Valley, 20, 22
Conifer, 163, 164
Conneaut Creek, 128
Conneaut Lake, 56, 110, 120, 126, 127
Conneautville, 110, 117, 120-122
Connellsville sandstone, 147
Connoquenessing Creek, 20
Connoquenessing sandstone, 33, 35, 69, 82, 98, 112, 149, 160, 171, 172, 181, 183, 193
Conway, 91, 94
Cooling, ground water for, 53
Corry, 57, 129, 131, 134, 139, 140
Cramer, 154
Crawford County, analyses of waters, 56, 62
  ground water in, 109-127
Creekside, 154
Crooked Creek, 128
Crossingville, 110, 122
Crow Island, 93
Cussewago Creek, analysis, 56
Cussewago Valley, hydraulic gradient, 119
Cuyahoga formation, 39, 113, 182, 203

D

Darlington, 92
Dayton, 54, 61, 68, 72, 74
Deckards, 124
Devonian system, 39
Dicksonburg, 56, 121, 122
Drainage, 12
  Pre-Wisconsin, 15
Drawdown curve, 119
Drillers terms, 64

E

Eaglehurst, 134
East Brady, 55, 56, 100, 104, 107
East Rochester, 91
Eastvale, 91
Edinboro, 134-137
Edinburg, 176
  buried valley near, 20
Elgin, 139
Ellwood City, 173, 174, 177
Emlenton, 105 195
Emrickville, 160, 162, 164
Endeavor, 143, 144
Enon Valley, 58, 177
Erie, 129, 134
Erie County, analysis of waters, 57, 62
  ground water in, 128-140
Ernest, 154
Erratics, 27
Escarpment, Lake Erie, 13
Ewing, 74

F

Fairview, 62, 129, 134, 136, 187, 188
Falls Creek, 162, 163
Fallston, 91
Farrell, 185, 191
Ferrona, well at, 63
Ferry Spring, 115
Filtration, 53
Fish Hatchery, Corry, 129
Flowing wells, 172, 183, 194, 205
Ford City, 54, 65, 72, 75
Forest County, analyses of waters, 57, 63
  ground water in, 141-144
Forty-foot sand, 34
Foxburg, 55, 100, 104, 105
Franklin, 23, 59, 194, 195, 197, 198
Fredonia, 187
Freedom, 91
Freeport, 72
  sandstone, 67, 81, 97, 159
French Creek, 23, 110
  analysis, 59
Frost, 9, 11
Fryburg, 55, 61, 98, 104, 106
Furnace Run, 72

G

Garland, 60, 208
  conglomerate, 35
Gas sand, 34
Geomorphology, 12
Georgetown, 94
Girard, 57, 62, 134-136
  shale, 131
Glacial drift, 27, 109, 129, 166, 178, 200
  ground water in, 45, 172, 183, 206
Glacial gravels, 77
  history, 16
  outwash, 18, 28, 110, 141, 166, 178, 192, 200
    ground water in, 45, 116, 192, 194
  striae, 17
Glaciated section, 13, 27
Glade, 22
Graceton, 63, 149, 154
Grand Valley, 206, 211
Gravels, 77
  deposits, pre-Illinoian, 28
  terraces, 15, 29
Greenfield, 138
Greenville, 17, 59, 63, 181, 185, 186
Ground water,
  for cooling, 53
  occurrence, 42-46
  quality, 49-53, 86-88, 102, 116, 132, 152
  recovery, 46-49
  removal of iron, 52
  source of, 40-42
Grove City, 59, 181, 182, 184, 185, 189, 190
Growing season, 9
Guys Mills, 120

H

Hadley, 188
Hamilton, 165
Harborcreek, 57, 134, 137
Hardness, 50
Hare Run, analysis, 57
Harrisburg peneplain, 14, 16
Harthegig, well at, 59
Hartstown, 56, 127
Head, 47
Heilwood, 154, 156
Henderson, 189
Henry Mills, 143
Hickory Township, spring in, 63
Holobar Beach, 120
Homer City, 154, 155
Homewood sandstone, 33, 34, 69, 82, 98, 112, 149, 160, 170, 172, 180, 183, 193
Hydraulic gradient, 119
Hydrogen sulphide gas, 194
Hydrograph, dug well at Sligo, 41

I

Illinoian glacial stage, 27, 28
Indiana, 153-155
Indiana County, analysis of waters, 57, 63
  ground water in, 145-156
Industry, 54, 81, 93
Infiltration crib, 47, 55, 85, 86
Intake of well, 48-49
Iron, effect of, 50
Iron-bearing waters, 52, 103
Irvine, 208

J

Jacksonville, 155
Jamestown, 127, 185, 186
Jefferson County, analyses of waters, 58
  ground water in, 157-165
Johnetta, 72
Joint, 43
Josephine, 154

K

Kansan glacial stage, 27
Kiskiminetas River, 30

Kittanning, 66, 72, 74
sandstone, 68, 81, 97
Knapp formation, 39, 202, 204
Knox, 55, 100, 104, 105
Koppel, 83, 91, 92
Krends, 187

L

Lake Erie escarpment, 13, 128
Lakeville, 123
Lander, 208
Lawrence County, analyses of waters, 58, 63
ground water in, 166-177
Leeper, 106
Leesburg, 190
Lincolnville, 123
Lindsey, 163
Linesville, 120, 127
Little Brokenstraw Creek, 19
Little Cooley, buried valley near, 19
Littles Corner, 125
Lottsville, 200, 208
buried valley near, 18
Lovell, 139
Lower Freeport coal, 67, 159
Lower Kittanning coal, 33, 68
Lowville, 138
Loyalhanna limestone, 38
Lubold spring, 62

M

Mahoning sandstone, 67, 80, 147
Mahoningtown, 58, 176
Mahoning valley, 19
Manorville, 72
Marienville, 57, 143, 144
Marion Center, 57, 152, 154
Mauch Chunk formation, 37
McIntyre, 154, 155
McKean, 136
McLane, 136
Meadville, 56, 109, 111, 113, 117, 118, 120, 125, 126
buried valley near, 19
shale, 39, 100, 114
Mercer, 59, 185, 190, 191
Mercer County, analyses of waters, 59, 63
ground water in, 178-191
shale, 33, 34, 82, 99, 112, 149, 160
Merrill, 93
Midland, 91
Millbrook, 59, 189
Mineral springs, 111
Mine water, effect on supply, 103
Mississippian-Pennsylvanian unconformity, 36
Mississippian series, 37, 100
Monaca, 47, 54, 55, 84-88, 91, 92
Monongahela formation, 31, 67, 79, 146
Monongahela River, 30
Morado Springs, 55, 85
Morgantown sandstone, 79, 147
Mosgrove, 74
Mosiertown, 56, 122
Mountain sand, 39, 69, 100, 102
Mountain Top Spring, 113
Muddy Creek, 19

N

Nebraskan glacial stage, 27
Nectarine, 199
New Bedford, 175
New Bethlehem, 104, 107, 108
New Brighton Heights, 91
New Castle, 173, 174, 176
New Galilee, spring at, 61
New Hamburg, 187
Newtown, 141
New Vernon, 59, 189
New Wilmington, 58, 173-175
New Wilmington Water Co., 63
Nickleville, 199
North East, 57, 131, 134, 138.
North Warren, 22
Nu mine, 72

O

Occurrence, ground water in
coal, 46
glacial drift, 45
sandstone, 45
shale, 46
Ohio River, analyses, 55, 87
terrace deposits, 29
valley, 77
Oil City, 59, 63, 194, 195, 197
Olean conglomerate, 33, 35, 113, 142, 193, 202, 203
Orangeville shale, 39, 114

P

Pardus, 163
Parker City, 72
Parker strath, 15
Parkers Landing, 105
Patterson, 91
Peneplain, 14
Pennsylvanian series, 31
Peorian interglacial stage, 27
Permeability, 43
Physiographic divisions, 12
Pittsburgh coal, 32
Pittsburgh sandstone, 146
Pittsfield, 208
Plain Grove, 175
Platea, 135
Pleasantville, 59, 195, 196
Pleistocene, 27
Pocono group, 38, 69, 83, 99, 113, 130, 142, 150, 153, 161, 172, 178, 182, 183, 193, 194, 203
Polk, 195, 198
Population, 2
Porosity, 42
Portage formation, 131
Pottsville formation, 13, 33, 69, 82, 98, 112, 142, 149, 160, 170, 180, 193, 194, 202
Precipitation, 6-9
relation to water level, 41
Pre-Illinoian gravels, 28
Pre-Wisconsin drainage, 15-26
Princeton, 58, 177
Public water supplies, 72-73, 85, 91, 104, 117, 133, 153, 162, 173, 184, 194, 206
Pulaski, 166, 173-175
Pumping test, 117
Punxsutawney, 58, 163, 165

Q

Quakertown shale, 112
Quality of water, 49-53, 71, 102, 162, 173, 184, 194, 205
Quarry Hill, 17
Quicksand, 116, 132

R

Rainfall, effect on yield of spring, 42
Raymilton, 195-198

Recent alluvium, 26
Red Bank Creek, 30
Reidsburg, 106
Relief, 13
Reno, 195, 197
Reynoldsville, 58, 159, 162-165
Riceville, 124
  shale, 130
Rimersburg, 42, 55, 98, 101, 104, 107
  spring at, 56
Robindale, 154
Rochester, 54, 84, 91, 92
Rock formation, 31
  permeability, 43
  porosity, 42
  water-bearing properties, 43
Rossiter, 154
Rosston, 72
Rouseville, 195-197
Rural Valley, 54, 73, 74
Russell, 60, 205, 209

S

Sagerstown, 56, 110, 120, 125
Sagamore, 61, 72, 74
Saint Petersburg, 55, 98, 103-105
Salamanca conglomerate, 204
Saltsburg, 153, 154
  sandstone, 67, 147
Salt water, 53, 71, 83, 84, 103, 116, 133, 153, 173, 189, 194, 205, 206
Sandstone, ground water in, 45
Sandy Lake, 41, 185
Sangamon interglacial stage, 29
Scandia, 36
Screens, 49
Seminole, 73, 74
Seneca, 197
Shale, occurrence of ground water in, 46
Sharon, 185, 191
  coal, 35
  conglomerate, 35, 113, 172, 181
  glacial striae on, 17
  sandstone, 17, 33
  shale, 33, 35
Sharpsville, 59, 63, 184-186
  sandstone, 39, 114, 181, 182
Sheakleyville, 188
Sheffield, 207, 210
"Shells," definition of, 64
Shenango sandstone, 39, 114
  shale, 114
Shippenville, 55, 104, 106
"Slate," definition of, 64
Sligo, 55, 56, 62, 99, 102, 104, 106, 107
  hydrograph of well at, 41
Smiths Ferry, 91
South Heights, 55, 91, 94
Spartansburg, 124
Springs, 62, 63, 110, 111, 113, 115, 131, 173, 194
  effect of rainfall on yield, 42
Springboro, 121
Stoneboro, 63, 185, 189
Structure, 39, 69, 83, 101, 151, 161, 172, 183, 205
Sugar Lake, 114
Summerville, 58, 108, 162-164
Surface deposits, 26, 76, 95, 129, 166, 178, 192, 200
Sykesville, wells in, 58, 158, 159, 163, 165

T

Tearing Run, 154
Temperature, 9, 11
Templeton, 65
Terrace, 166
Terrace gravels, 15, 29, 141
  along Clarion River, 30
Thiem's equation, 117
Thompsons Station, 25
Tide, 154
Tidioute, 206, 207, 210
Till, 28
Tiona, 36
Tionesta, 141, 144
  valley, 141
Titusville, 56, 62, 117, 120, 124
Townville, 124
Tryonville, 124
Two Lick Creek, 63, 153

U

Union City, 134, 139
Unconformity, 36, 99
Upper Devonian series, 39
Upper Freeport coal, 33, 67, 80, 149, 159
Utica, buried valley near, 23

V

Valley Ice Co., drillers log, 77
Vanport, 93
  limestone, 33, 68, 81, 97, 159
Venango, 125
Venango County, analyses of waters, 59, 63
  ground water in, 192-199
  oil sand group, 112, 130
Volant, 173, 174

W

Wampum, 173, 174, 177
Warren, 60, 206-210
Warren, buried valleys near, 20
Warren County, analyses of waters, 60
  ground water in, 200-211
Water-level fluctuations, 41
Water table, 44, 48, 84
Waterford, 57, 62, 134, 137
Wattsburg, 57, 129, 138, 139
Wehrum, 151, 154
Well screens, 49
Wesley, 198
  glacial outwash at, 18
Wesleyville, 134
West Aliquippa, 61, 91, 93
West Bridgewater, 91
West Hickory, 63, 141, 143, 144
West Kittanning, 66
West Lebanon, 147, 155
West Middlesex, 59, 178, 185, 191
West Pittsburgh, 174
West Reynoldsville, 163
Wheatland, 185
Wilmington, well near, 63
Wisconsin glacial outwash, 18
Wisconsin glacial stage, 27, 28
Wishaw, 165
Wolf Creek, 179
Worthington, 68, 73, 74
Worthington peneplain, 14
Wrightsville, 208
Wurtemberg, 171

Y

Yarmouth interglacial stage, 28
Yatesboro, 73
Youghiogheny River, 30
Youngsville, 60, 207, 208